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ORIGINAL ARTICLES.

I.—Studies in Edrioasteroidea. V. *Steganoblastus*.[1]

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(PLATE XV.)

Previous History.

THIS form was first made known in 1897, by the late J. F. Whiteaves, in a paper entitled "Description of a new genus and species of Cystideans from the Trenton Limestone at Ottawa" (Canad. Rec. Sci., vol. vii, No. 5, pp. 287–92). This part bears on the wrapper the date "January, 1897", which is obviously erroneous, since the author dated his own contribution "April 28th, 1897", and copies of it were first received in London on July 31 of that year.

In that paper the species received the name *Astrocystites ottawaensis*, and was regarded as "most nearly related to *Asteroblastus*, Eichwald, and . . . probably referable to the same family". In a letter sent to Dr. Whiteaves by the next mail, I pointed out difficulties in this interpretation of the structure, as well as difficulties in the name *Astrocystites*. "You can," I wrote, "hardly have been aware that Haeckel, in 1896, separated *Asteroblastus tuberculatus* of Schmidt from *A. stellatus* under the new generic name of *Asterocystis*." I further pointed out that the termination *-ites* was frequently dropped, and was no real distinction; also that ἀστήρ and not ἄστρον was the correct word to use in composition for the sense intended by Dr. Whiteaves. A change of name therefore not only would avoid confusion but seemed to me justified. Dr. Whiteaves accepted my view, and in a "Postscript" (tom. cit., p. 395, January 7, 1898) published the name which I suggested to him—"*Steganoblastus*, from στεγανός, closely covered, with reference to the large covering plates and covered mouth." In this Postscript he inadvertently alluded to the species as *Steganoblastus canadensis* instead of *S. ottawaensis*.

In consequence of my remarks on the structure, Dr. Whiteaves kindly lent me the two specimens belonging to the Geological Survey of Canada, which, with an imperfect specimen lent me by Mr. Walter R. Billings, made up all the known material. The first results of my examination were summarized in Lankester's *Treatise on Zoology*, vol. iii, pp. 209–10, text-fig. vii (1900), where I founded for the reception of this genus the Family Steganoblastidæ of the Class Edrioasteroidea.

[1] Study IV appeared in the Geol. Mag. for March and April, 1914.

In September, 1906, Dr. Whiteaves reprinted his original description, followed by a complete extract from the *Treatise*, in *Palæozoic Fossils*, vol. iii (pp. 316–21), published by the Geological Survey of Canada. My drawings of *Steganoblastus* were also among the very large number of text-figures which Messrs. Delage and Hérouard paid me the great compliment of reproducing in reduced facsimile in their *Traité de Zoologie concrète*, tome iii, "Les Echinodermes" (pp. 415, 416, Paris, March 30, 1904). The Family Steganoblastidæ is accepted by Dr. F. Springer in the second edition of Eastman's *Zittel* (1913).

The present paper gives the evidence on which my textbook account was based.

Material.

The specimens are the three syntypes of Whiteaves, and may be distinguished as A, B, and C. All were obtained from the Trenton Limestone at Division Street, Ottawa. The precise horizon has nowhere been stated.

Specimens A and B were collected by Mr. John Stewart in 1886, and are in the Victoria Memorial Museum, Ottawa. Specimen C was collected by Mr. Walter R. Billings, in whose possession it remains.

A is an almost perfect theca with two columnals. It is the original of Whiteaves' figs. 1 and 2, and of Pl. XV, Figs. 1, 3, 4, 6, 7, in the present paper. It is hereby selected as the holotype.

B is a theca crushed in the left anterior interradius and adjoining radii, with portions of three columnals. It is the original of Whiteaves' fig. 3, and of our Pl. XV, Figs. 2, 5.

C is a much broken and crushed theca with no columnals.

"All three of these specimens, when found, were," says Whiteaves, "almost completely covered with a very tenacious shaly limestone." This had been for the most part skilfully removed before the specimens were sent to me, but the pores and the outlines of the plates were still obscured.

General Description.

The chief features can readily be gathered from the slightly restored figures 1 and 2, here reprinted, with slight modification, from the *Treatise* (1900).

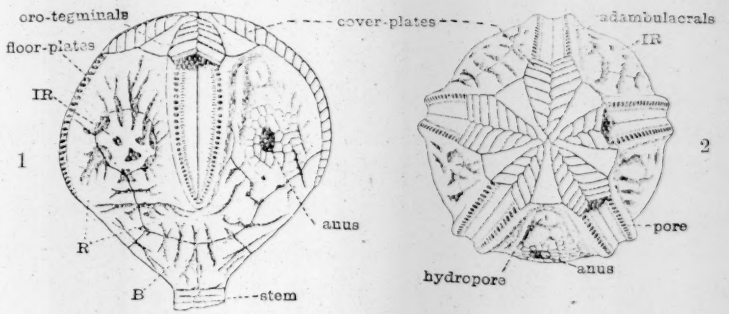
The most obvious difference from Edrioasteroidea belonging to the Family Edrioasteridæ lies in the Stem of normal pelmatozoan character. This supports a Theca of regular pear shape.

The Theca consists, as in other Edrioasteroidea, of two systems of plates: (1) an adoral system, (2) an adapical system. From the tegminal region above the peristome, the Adoral System radiates in the form of five subvective grooves, passing straight along the perradial meridians, to a level almost exactly two-thirds of the way down the long axis of the theca. From the stem, at the opposite pole, the Adapical System spreads upwards, supporting and passing in between the five grooves, to abut finally on the interradial elements of the tegmen. In one of the interambulacral areas of this system, lies the anus, marking the posterior interradius.

Description of the Specimens.

The measurements of the piriform theca in specimen A are approximately: height, 19·5 mm.; greatest diameter, 18 mm., this being at 8·5 mm. from the summit.

Except for the tegminals and cover-plates, all the thecal elements are closely united, so that it is difficult to distinguish the sutures. This difficulty is enhanced by the pitted ornament of the surface, and by the very deep folding of the plates which form the adapical system. On the other hand, as one removes the tenacious black matrix from the depths of the folds, one realizes that they represent a system of rhomb-ridges and axial folds on the plan so common in Pelmatozoa; and, remembering that in such cases the folds are at right angles to the sutures, one is able with somewhat greater confidence to trace the limits of the plates. In some cases it may be that the arrangement of the folds indicates rather the original constitution of the young individual (or of its ancestor) than any actual



Steganoblastus ottawaensis.

Fig. 1. Restored view of theca from left posterior interradius.

Fig. 2. Restored view of oral surface.

Both drawings are based mainly on specimen A. × 2 diam.

separation of plates in the adult. It seems plain that the tendency of the species is to fuse the originally indefinite smaller plates into a few larger plates of definite arrangement (cf. Text-fig. 3).

The plates distinguishable in the adapical system (Text-fig. 1) are five basals, five radials, and in each interradius a varying number of interambulacrals. From a strictly morphological standpoint, one should perhaps also include in this system the floor-plates of the subvective grooves.

The Basals are of the pentagonal shape usual in normal crinoids. As the following measurements from specimen A show, they are a little lower on the posterior side of the theca, owing to the space required by the anal plates. The measurements are in millimetres and are taken along the surface of the theca.

	l. ant.	l. post.	post.	r. post.	r. ant.	ant.
Height of basal	5·6	5·5	5·1	5·2	5 7	
Height of interbasal suture	4·6	4·0		3·5	4·2	4·25

The Radials are of the roughly pentagonal shield-shape usual in normal crinoids and in blastoids. Since they have no brachial facet, but are notched for the excavation of the subvective grooves, they more closely resemble the radials of blastoids. The basi-radial and interradial sutures can be traced without excessive difficulty; the lengths of the latter, in the case of the anterior radial of specimen A, are left anterior 3·5 mm., right anterior 4 mm.

From the top of the interradial sutures, the shoulders of the radial slope upwards towards the subvective groove, and the sutures bounding them can be traced for some distance. The point at which they meet the flooring-plates of the groove cannot, however, be distinguished, owing to the close union of the various plates in the neighbourhood of the groove. Estimated roughly, for the anterior radial as before, the level of the top of the radial would be about 5 mm. from the lip, or distal end, of the groove; and the distance of the lip from the lower apex of the radial is about 4·1 mm.

The rhomboidal area above the shoulders of the radials and between the grooves is filled with Interambulacral plates. The precise number and arrangement of these varies in the different areas, and in all except the posterior area their outlines are hard to see (Text-fig. 3). To judge from the folds, three or four small plates have joined in the centre of each area, except the posterior, to form a relatively large plate of somewhat swollen appearance (IR). This plate rests on the radials, and other smaller plates lie between it and the grooves.

The posterior area, which is more swollen and a trifle wider than the others, measuring almost exactly 10 mm. from lip to lip of the bounding grooves, is filled with a larger number of plates. Except near the boundaries of the area, these are more loosely united, so that the sutures are readily seen. About the centre of this area in specimen A the plates are rather sharply depressed; but in B the corresponding depression is very slight, so that it has here proved easier to remove the matrix, and thus to disclose seven plates converging to a point, where doubtless was the vent. These seven Circumanal plates are surrounded by about fifteen other Periproctal plates, equally well defined, very diverse in shape but never long and tapering. Outside these again come plates less well defined and therefore less easily counted, but in total number about nine, one being interradial and resting on the radials, and four bounding the sides of the periproctal area and meeting above it in an interradial suture. The twenty-two periproctal plates are but faintly pitted, and each has an equably swollen surface. The nine bounding interambulacrals, however, are coarsely folded on their abanal margins, and the folds meet similar folds from the radials and from the adambulacral plates.

By Adambulacral plates I mean those which lie between the last set of plates and the grooves; but whether they are really distinct from the floor-plates of the grooves is uncertain. To this point we shall recur.

At the adoral end of the interambulacral area there lies in the posterior interradius, and apparently in the other interradii, a single

plate, continuous with the adambulacral series, and abutting above on the corresponding oro-tegminal. In the posterior interradius this plate occupies a larger area than in the others, and is much more swollen. Close examination under suitable illumination detects in this plate, in all three specimens, a meridional dark line. This is not a suture, for it is waved and does not reach the edges of the plate. It may represent the Hydropore.

The Ornament of the adapical system consists of the axial folds already mentioned, and of a number of pits.

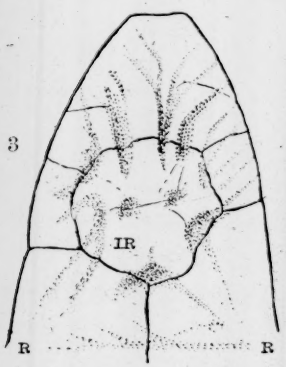
The Axial Folds in the lower, proximal or adcolumnal region of the theca are fairly regular. From the lip of each radial there run four main ridges, one pair horizontally to the lips of the adjacent radials, one pair downwards to the middle of the base of the adjacent basals. These main ridges thus enclose triangular spaces, namely an almost equilateral triangle bounded above by the horizontal ridges, and interradial in position; an acute-angled triangle with its base on the columnar suture, and radial in position. The interradial triangle encloses a smaller, less regular triangle of ridges. The radial triangle encloses two shorter ridges also springing from the base and meeting at a wider angle (*circa* 90°) at about one-third the height of the radial triangle itself. The triangular interambulacral area, above the main horizontal ridge, contains ridges crossing the sutures of the various plates already described as interambulacrals and adambulacrals.

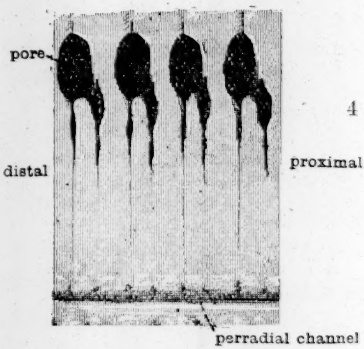
The folds between the ridges are very deep, especially in the interambulacral area, notably a fold just below the adoral interambulacral (Text-fig. 3). The removal of the matrix from these is extraordinarily difficult, and has therefore only been accomplished in one or two places. The operation led to no discovery of pores or any system of respiratory folds, and it may be inferred that the sole effect of the folding is to endue the theca with a quite exceptional rigidity.

The Pits cover the whole outer surface of the theca, including all the elements of the adoral system (Pl. XV, Figs. 2, 3). They have in many cases been worn away from the more prominent parts, either in the process of cleaning or, as there is some evidence to show, before the fossil was embedded in the matrix. They seem to lie even in the depressions of the folds, although not quite so well marked there. The pits seem to have been set most closely on the cover-plates and tegmen, and in consequence may there assume a more hexagonal outline. Elsewhere they are more circular. They vary in size, but have as a rule a diameter of about ·2 mm. Though they have no definite arrangement, they tend to lie along the edges of the cover-plates and along the sides of the larger folds. Occasionally there is a tendency to similar seriation at a definite angle to the sides of the grooves, as though marking the original adambulacral plates. These structures are pits, not pores, for one cannot imagine pores on cover-plates, and in any case they disappear entirely when worn down. No definite structure can be distinguished in them, but their complete resemblance to the spine-pits of Asteroidea and the lack of any other explanation render it highly probable that they lodged spines.

The Subvective System consists of five broad radial grooves leading to a subtegminal mouth. The grooves are bounded by Floor-plates,

one series down each side of a groove. The two series meet along the perradius in a distinct straight suture. In each series the floor-plates are united by a very close suture, or are even fused. The sutures can most readily be detected at the distal end of the groove, near the lip (Pl. XV, Fig. 3); but their former presence is clearly marked all the way up by a series of pores, similar to the pores between the floor-plates (so-called ambulacrals) of ordinary Asteroidea, and markedly resembling those in *Edrioaster*. That these structures are pores is proved, not merely by this external resemblance, but by distinct signs of their passage through the test wherever that is broken or ground away. The pores have an elongate-ovate outline on the surface, the broader end lying just below the edge of the groove, in other words just below the attachment of the cover-plates. The narrower end points towards the perradius, and merges into the suture between the floor-plates, which in its turn dies away before joining the perradial suture.





Steganoblastus ottawaensis.

FIG. 3. An interradial area of specimen A, to show the direction of the folds, and the occasional traces of sutures at right angles thereto. × 4 diam.

FIG. 4. Portion of the side of a subvective groove, to show the pores between the floor-plates, and the depressions on the floor-plates. × 16 diam.

In tracts that have not been so well cleaned from matrix as others there occasionally appears to be another series of smaller piriform pores, between the others, and nearer the perradius (Text-fig. 4). Further cleaning, however, shows that these are not pores but depressions. Each such depression is moreover connected with the pore on its distal side by a faint groove sloping downwards from the main pore to the piriform depression.

Below the pores and the piriform depressions, that is to say nearer the perradius, is a slight swelling of the groove-floor, so that a faint rounded ridge separates the poriferous tract from the smooth floor of the groove. In other words, there is a perradial channel. The sutures continuing the pores, and the channels continuing the piriform

depressions, cross this ridge at right angles, and so break it up into a row of rounded eminences, producing a toothed appearance.

At the distal end of the groove the floor-plates rapidly decrease in size, and this series is rounded off before the actual lip of the groove is reached. The distance between the end of the floor-plates and the lip seems to vary in the different radii. That in which best results have been obtained by preparation is the anterior groove of specimen A (Pl. XV, Fig. 3), but this is confirmed by other grooves so far as it has been possible to clean them. That the distal end of the groove was quite free of floor-plates is proved by the continuation of a double row of pits over the lip and along the middle of the groove, up to the end of the floor-plates. The sutures bounding these terminal floor-plates are distinct all round, and the floor-plates are seen resting on the grooved surface of the radial. Apparently, however, the radial does not actually pass right under the floor-plates, but is cut away beneath their adradial region, so that the pores between the floor-plates pass through into the thecal cavity.

The floor-plates in this part of the groove at any rate appear to have their outer boundary at the level of the pores. Owing to the close union of the floor-plates, not only *inter se*, but also with the radials and adambulacrals, it is impossible to trace any bounding suture along the edges of the groove. It seems, however, a legitimate inference that a generally similar relation of the floor-plates to the adjacent thecal elements prevails, or did in earlier stages prevail, all the way up the groove; at all events, it is clear that the floor-plates and adambulacrals are independent morphological elements, and this is a point of much theoretical importance.

At the distal end of the groove it is plain that the floor-plates of one side alternate with those of the other side.

The Cover-plates are best preserved in specimen B (Pl. XV, Figs. 2, 5; Text-fig. 5). In no case are they retained as far as the distal end of the groove, but there is no reason to doubt that they were continuous from the tegmen to the extreme end of the floor-plates. In the upper half of the right anterior groove, starting about one plate below the distal end of the oro-tegminal, there are nine cover-plates in a length of 5 mm. The proximal of these plates has a length of 2·5 mm.; the distal one a length of 1·8 mm. Nearer the oral pole the cover-plates are more irregular in shape and size, especially in this r.ant.radius of this individual. Over the greater part of the groove the cover-plates alternate regularly and meet in a zigzag suture; but at the proximal end smaller plates may be intercalated along the middle line. In specimen A there are no such intercalated plates, but the median suture in the proximal region becomes curved and interlocking (Text-fig. 6).

The relation of the cover-plates to the floor-plates appears to be quite regular. There is a cover-plate to each floor-plate, and, so far as can be ascertained after prolonged preparation and study, the sutures between the cover-plates coincide with those between the floor-plates. Thus the pores, which, as already stated, lie just below the attachment of the cover-plates, open under the sutures as in *Edrioaster*.

The thickness of the cover-plates about half-way down the r. ant. radius of specimen B is not more than ·35 mm. In many cases the cover-plates have been pulled or pressed down into the groove, but when preserved in what would seem to be their normal position they form a prominent rounded arch over the groove. The sutures between adjacent cover-plates, as well as the median suture, are slightly depressed and bordered by spine-pits. The suture between the cover-plates and the adambulacrals is flush, and the curve of the cover-plates passes over, though with a distinct bend, into that of the adambulacrals. The suture is not a straight line, but a series of curves, the convex outer edges of the cover-plates fitting into slight concavities in the adambulacral margin. The position and number of the axial ridges on this margin indicate that the original adambulacral elements coincided in number but alternated in position with the cover-plates, and therefore also with the floor-plates. This suture, then, is essentially a zigzag suture between two sets of alternating

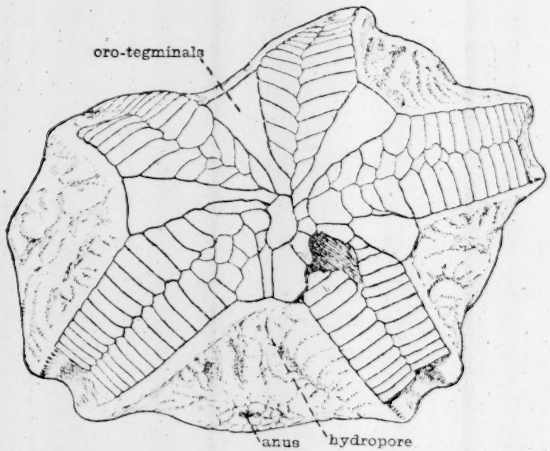


FIG. 5. *Steganoblastus ottawaensis*. Specimen B viewed from above, for comparison with Pl. XV, Fig. 5. × 4 diam.

plates. In consequence of this arrangement, one would expect to see along the edges of the groove, when the cover-plates are removed, a series of depressions or facets for the reception of the cover-plates. Unfortunately the edges have in nearly every case been worn enough to remove all trace of these very faint depressions, and it has only been by dissecting away some cover-plates at the end of the r. ant. ray in specimen B that I have been able to distinguish anything of the kind.

The Tegmen is best studied in specimen A (Pl. XV, Fig. 7; Text-fig. 6). Here the cover-plates are more regular than in B, and the arrangement of the whole follows an obvious symmetry, which, from its resemblance to that in other Pelmatozoa, must be regarded as the normal. In addition to the cover-plates, the tegmen contains

only five plates, which have already been alluded to as the oro-tegminals. These abut by their distal broader ends on the inter-ambulacrals, and gradually narrow as they pass, between the converging and narrowing series of cover-plates, towards the oral pole. As is usual in Pelmatozoa, only three of them meet there: the posterior and the right and left anterior. There is, however, a difference from the usual plan in that these three can scarcely be said to meet in a triradiate suture; but the posterior plate passes between the other two and with its pointed apex actually touches the proximal cover-plate of the anterior radius, so that in this individual the two anterior oro-tegminals do not touch one another as is customary and as they do in specimen B.

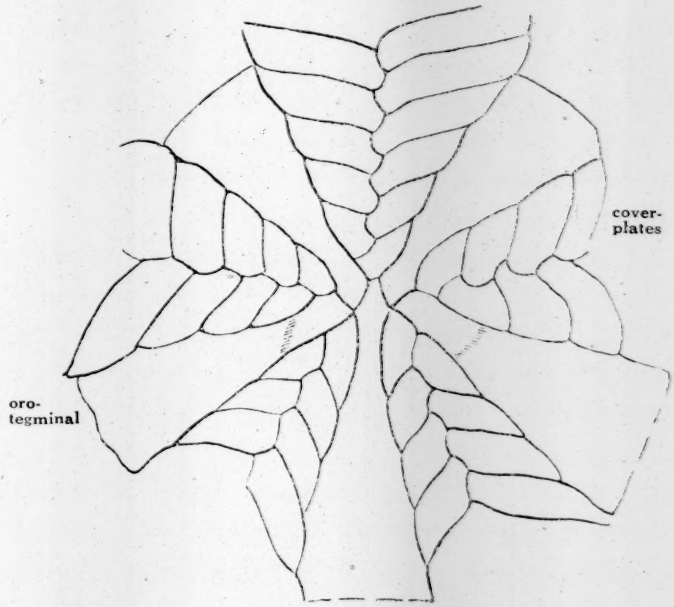


FIG. 6. *Steganoblastus ottawaensis.* Exact drawing of the sutures in the tegmen of specimen A. × 8 diam.

These three oro-tegminals have the same general shape. Each tapers gradually as the subvective grooves bounding it converge, then, as the grooves are rounded off, it expands, and again tapers rapidly to a sharp point, thus resembling a spear-head. Each of these three plates appears to be one continuous element, from the pointed apex to the broad straight base.

The two other oro-tegminals, the r. and l. post., are of the same general shape, except that they do not end in a spear-head, but in an oblique suture, abutting on the adjacent side of the spear-head of the r. and l. ant. oro-tegminal respectively. At the extreme end of this

suture they may just touch the post. oro-tegminal. It is not so certain that these two plates are continuous elements. They seem to be crossed by an obscure oblique suture at the level of the second cover-plate of the adjoining grooves. It is not impossible that the proximal portion of each of these plates may represent the proximal cover-plate of the l. ant. and r. post. grooves respectively. Those are the grooves to which the supposed cover-plates would naturally belong, in spite of the asymmetry involved.

The tegmen of specimen B is so much more irregular and asymmetrical that it cannot be described in detail. The r. and l. ant. oro-tegminals have the spear-head end. The proximal end of the l. post. oro-tegminal is almost squeezed out of existence between the contiguous grooves. The r. post. oro-tegminal is transversely divided, and its proximal portion is nearly as large as the distal portion and swells out to almost the same width. The post. oro-tegminal is also divided transversely, and its distal portion is again split by meridional sutures into three elongate plates.

The Stem appears to have had a circular section, though in both A and B it is slightly crushed. The diameters in B are 5·2 mm. and 3·75 mm., giving a mean of 4·47 mm. The lumen in B has diameters *circa* 2·5 mm. and 1·75 mm., giving a mean of *circa* 1·9 mm.

The columnars are irregular plates, differing considerably in height and width, but tending apparently to form pentameres alternating about more or less radially disposed sutures. In the post. interradius of A the combined height of four such pentameres is 1·6 mm.; these alternate with three pentameres in r. post. IR having almost the same height. In the l. ant. IR of B the combined height of three pentameres is 2·7 mm., and in post. IR two pentameres have a combined height of 1·8 mm.

There seem to be traces of spine-pits on the pentameres.

Relations of *Steganoblastus*.

The meanings of all the structures that have just been objectively described will have to be discussed in a later paper. Here it is only the immediate conclusions that can be drawn.

First, the absence of brachioles, inferred from the lack of brachiole-facets and the presence of large cover-plates, proves that *Steganoblastus* is not a blastoid, not even one of the Protoblastoidea, as was at first supposed. It also proves, if proof be needed, that it is not one of the Cystidea Diploporita.

Secondly, the structure of the subvective groove, with its floor-plates and cover-plates, and its pores between the floor-plates, is paralleled by Edrioasteroidea alone among Pelmatozoa, and in that Class most closely by *Edrioaster*, though there are minor differences.

Thirdly, the presence of a stem, and the enhanced pentamerism of the thecal structures thereby induced, render it impossible to place *Steganoblastus* in the Family Edrioasteridæ. It has therefore been necessary to establish for it the Family Steganoblastidæ (*Treatise*, 1900, p. 209).

EXPLANATION OF PLATE XV.

Steganoblastus ottawaensis.

FIG. 1. Specimen A, from the posterior interradius, showing periproctals and, above them, the supposed hydropore.
,, 2. Specimen B, from the posterior interradius, showing the same features.
,, 3. Specimen A, the lip of the anterior subvective groove, showing pores, adradial suture, and spine-pits. For exigencies of lighting, the perradius is sloped downwards from right to left. × 5 diam.
,, 4. Specimen A, from the right anterior interradius.
,, 5. Specimen B, adoral view; compare Text-fig. 5.
,, 6. Specimen A, adapical view.
,, 7. Specimen A, adoral view; compare Text-fig. 6.

All the figures are from photographs by Mr. H. G. Herring, and all, except Fig. 3, are enlarged 3 diameters.

The Text-figures are based on pencil drawings by Mr. G. T. Gwilliam.

II.—The Zones of the Beaufort Beds of the Karroo System in South Africa.

By D. M. S. Watson, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

PROFESSOR H. G. Seeley, in his well-known paper on *Pariasaurus Baini*, incidentally mentioned that the Beaufort Beds, in which it was found, could be divided up into zones on the evidence of the reptiles they contained. Dr. R. Broom, following out this suggestion, went further and divided them into the

Cynognathus
Procolophon
Lystrosaurus
Cisticephalus
Endothiodon
Pariasaurus
} Zones.

This division is perfectly correct and cannot at present be improved upon, but beyond saying to which zone all the species which he recognized as distinct belong, Broom has never offered any evidence in support of it or indeed explained the real meaning of the division.

During my visit to South Africa I had the good fortune to collect from all these zones, and propose in this short paper to explain the evidence I collected and then to show that from the evidence of specimens in museums it is possible to construct a map which is self-consistent.

The three lowest zones are best seen round Beaufort West. Beaufort West stands on the *Endothiodon* zone, and to the south there is a great expanse of slightly rolling country, the Gouph, which is obviously composed of rocks lying below those on which the town is built. To the north the magnificent escarpment of the Nieuveld rises about 3,000 feet above the plain.

The beds which form the Gouph have been very extensively collected from by T. Bain, H. G. Seeley, The Survey, R. Broom, J. H. Whaits, and the author. They yield several species of Pariasaurs, none of which have an armour more extensive than

that of *Pariasaurus Baini* as described by Seeley, that is, they have only a few small scutes round the neural spines of the dorsal region. Less common are the remains of Deinocephalia, both Tapinocephaloids and Titanosuchia and many diverse types of Therocephalia. Small Dicynodons occur in considerable numbers, but no large forms of Anomodont have ever been found, and the beds have been so thoroughly searched that their absence or excessive rarity is assured.

The *Endothiodon* beds, which are seen in the field to follow those of the *Pariasaurus* zone, have been searched by T. Bain, very largely by J. H. Whaits, and to a much less extent by the author. They have never yielded any Pariasaurian remains (except a very small femur) and no Deinocephalians. There are many Therocephalia, particularly Gorgonopsids, including *Gorgonops torvus*. There are numerous large Endothiodons, and all the Dicynodons are very small.

At the top of the Nieuveld escarpment, for example at Kuils Poort Nek, about 12 miles north of Beaufort West, there is a fauna, collected at various places along the escarpment by T. Bain, H. G. Seeley, R. Broom, The Survey, J. H. Whaits, S. H. Haughton, and the author, which has as its commonest and most striking constituent large Dicynodons, i.e. types with a skull length of 25 cm. or more. There are also Therocephalia and Gorgonopsids, quite different from those found below, and the much armoured Pariasaurians of the genus *Propappus* occur in considerable abundance. Judging from this district, which has been so extensively worked as to afford most satisfactory evidence, the zones are characterized by the following features:—

The *Pariasauras* zone, by the occurrence of large, slightly armoured Pariasauria and Deinocephalia and the absence of any large Anomodonts.

The Endothiodont zone is characterized by the occurrence of *Endothiodon* and other large Endothiodonts and peculiar Gorgonopsids, and by the total absence of large Dicynodons.

The *Cisticephalus* zone is characterized by the presence of many large Dicynodons and *Propappus*, and other much ornamented Pariasaurs and the absence of any large Endothiodonts.

The three upper zones can only be studied in the east of Cape Province. Round the towns Aliwal North and Burghersdorp the *Cynognathus* zone is very well exposed, and has been collected from by A. Brown, R. D. Kannemeyer, R. Broom, and the author. It yields a fauna the most abundant constituents of which are the large Dicynodonts of the genus *Kannemeyeria*, Cynodonts, particularly those of the family Cynognathidæ, and the Thecodont *Erythrosuchus*.

Passing north-westward of the rich locality of Winnaarsbaken at the farm Klip Kuil, a bed of extremely hard sandstone with clay galls and fragments of bone is clearly seen to dip under the *Cynognathus* beds. In this bed I found fragmentary limb-bones apparently of *Lystrosaurus*, and two complete maxillæ and a dentary of *Procolophon trigoniceps*. In the river which intersects this bed and about 200 yards below in a bed of sandstone about 100 feet below that which contains *Procolophon*, I obtained *Lystrosaurus* remains,

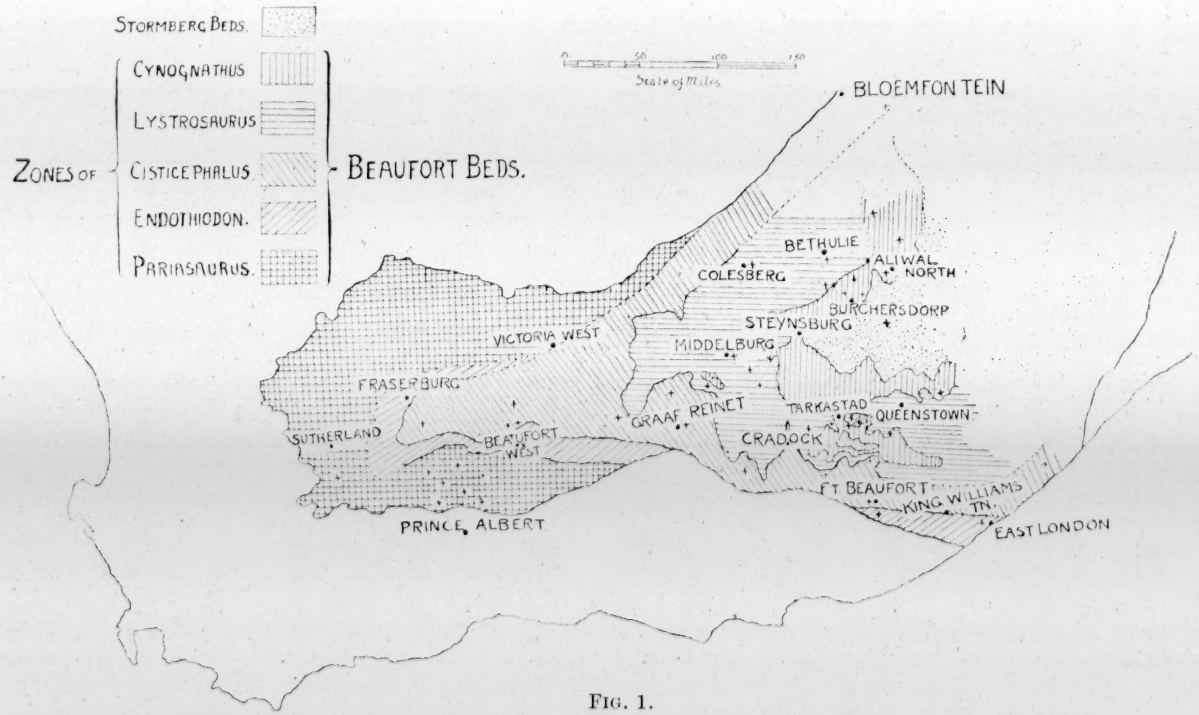


FIG. 1.

Geological Sketch-map of South Africa to illustrate the distribution of the zones of the Beaufort Beds. The bottom of the Beaufort Beds is copied from Rogers & Du Toit's map on the geology of Cape Colony.

+ Crosses are selected fossil localities, each yielding fossils of the zone in which they lie. The *Procolophon* zone is represented by the line between the *Lystrosaurus* and *Cynognathus* zones.

Judging from this map it is not improbable that there should be an exposure of the *Endothiodon* zone south of Pearston, but I know of no field evidence of its occurrence.

one skull being apparently *L. curvatus* (Owen). Further to the west, at Venterstad and Bethulie Bridge, *Lystrosaurus* again occurs, specimens being in the British and Albany Museums.

About 80 miles south of Burghersdorp, in the district round Tarkastad, I again obtained clear evidence of the order of superposition of these three zones. In the Field Cornetcy Upper Zwaart Kei of District Queenstown there is a hill, Tafelberg, the watercourses on the sides of which give excellent sections. At two localities, Haslop Hill to the north-east and Donnybrook to the south-west of this hill, I obtained *Procolophon* at nearly the lowest level explored. This reptile occurs in a thin zone in the great mass of deep-red mudstone which forms all the lower part of the hill.

On the farm Tentergate, which is on the west side of Tafelberg at a horizon about 500 feet above the *Procolophon* zone of Haslop Hill, I found in a thin sandstone a broken dentary of *Tribolodon frerensis*, the type-specimen of which was found by Professor Seeley in the *Cynognathus* zone of Lady Frere. The upper part of Tafelberg is composed of grey shales and yellow-grey sandstones, which are lithologically similar to the Molteno Beds. In the Albany Museum there is a dorsal vertebra of a Dinosaur collected by Mr. D. White at Tafelberg; as no Dinosaurs have ever been found in the Beaufort Beds, this affords very strong evidence that these grey beds are really of Molteno age. About 20 miles west of Tafelberg, in the lowest beds exposed in the farm Newtondale, I obtained *Lystrosaurus declivis* (?) in a deep-red sandstone and fragmentary *Lystrosaurus* remains in a yellow sandstone. These beds are the lowest of those occurring on this farm, and are clearly seen in the field to lie below the *Procolophon* zone of Haslop Hill. The only common animal of the *Procolophon* zone is *Procolophon* itself.

The *Lystrosaurus* zone is characterized by that animal, which occurs almost to the exclusion of other forms; there are in the British Museum some peculiar large *Dicynodon* skulls from Bethulie which seem to have come from this zone.

The *Cynognathus* zone is sharply marked by *Kannemeyeria*, Cynognathids, and *Erythrosuchus*.

Accepting the possibility of identifying these zones by the facies of the fauna they contain, a presumption which is justified by all experience and by the great length in time of the zones (the six cover the entire interval from low in the Permian to near the top of the Trias), it is easy by determining from specimens in museums the horizon of a sufficient number of localities to construct a geological map. This is done in Fig. 1 (p. 205), where the crosses represent some known fossil localities almost all represented in the British Museum. I do not intend to give a list of these localities and the fossils from them, because it is difficult to do so usefully without a systematic revision of the South African fossil reptiles. The more important and critical localities are discussed below.

The *Procolophon* zone is so thin that it cannot be separately represented, but is indicated by the line of junction of the *Lystrosaurus* and *Cynognathus* zones. *Procolophon* has been found at Whittlesea and Donnybrook, Queenstown District; Haslop Hill,

District Tarka; Fernrocks, near Tafelberg Station, District Middelburg; Klip Kuil, District Albert; and at a locality on the Orange River a few miles west of Aliwal North. It also occurs in the Orange Free State. These localities fix the line with some accuracy and give the bottom of the *Cynognathus* zone, the upper limit of which is the bottom of the Molteno Beds, whose outcrop has been partly mapped by the Survey and is obvious from their marked lithological characters. The field evidence seems to show that the upper part of the Great Winterberg is composed of Molteno Beds formerly continuous with those of Tafelberg. The area of *Cynognathus* beds north-west of Graaf Reinet depends on the type-specimen of *Cynochampsa laniaria*, Owen, from Rhenosterberg. This specimen is quite certainly a Cynognathid, almost certainly a Diademodon. The most northerly *Cynognathus* zone locality which I know is Smithfield, from which the British Museum has *Erythrosuchus*.

The distribution of the *Lystrosaurus* zone is well fixed by the occurrences at Klip Kuil, Colesberg, round Middelburg, and Newtondale in Tarka. North of Fort Beaufort its distribution on the map depends on a thick mass of light-yellow sandstone which I believe to belong to this zone. Large Dicynodons indicating the *Cisticephalus* zone are found at many localities round Fort Beaufort. The occurrence of the type-specimen of *Pariasaurus* at Blinkwater suggests the occurrence of the zone of that name, but specimens in the British Museum which I have strong reasons for believing to belong to that type-specimen are of a type which would now be called *Propappus*, a typical *Cisticephalus* zone form.

The occurrence of the type-specimen of *Gorgonops torvus* at "Mildenhalls", which is probably the farm now owned by the family of that name a few miles south of Fort Beaufort, shows definitely the occurrence of the *Endothiodon* zone, for another and absolutely identical individual has been found in the zone at Beaufort West. The small Endothiodonts found at East London suggest the same horizon, though they might be of *Cisticephalus* age.

The *Cisticephalus* locality north of Bedford is on the Kagaberg, where *Dicynodon tigriceps* occurs, that near Aberdeen depends on the type-specimen of *Platypodosaurus robustus*, Owen, from Camdebo. Large Dicynodons probably of this horizon in the Bloemfontein Museum come from the Modder River about 20 miles east of that town. Similar but very fragmentary remains have been obtained at Senekal and Harrismith.

The typical large lightly armoured Pariasaurs of the zone of that name have never been found except in the Gouph. The Deinocephalian *Moscops* comes from Dams Laagte, south of Sutherland. As the large bones of these reptiles when weathered out are only very slowly destroyed and are very conspicuous objects, the fact that they have never been found elsewhere gives good reason for believing that this zone either does not occur out of this district or, much less probably, is not fossiliferous.

The map constructed in this way from many more localities than those actually marked is self-consistent, and I think does make an approximation to the real general distribution of these zones in

those regions, a wide strip between Aliwal North and Fort Beaufort, and the district round Beaufort West, of which I have a personal knowledge. It is, I hope, fairly satisfactory, but the country between Graaf Reinet, Beaufort West, Victoria West, and Colesberg has as yet yielded so very few fossils as to be in the last degree speculative. The Free State fossils are so few and so badly localized that that province is practically a *terra incognita*. The most interesting feature is the occurrence on Harrismith commonage of *Lystrosaurus*, a large *Dicynodon*, and typical Deinosaurs of the Red Beds of the Stormberg Series, a fact which seems to indicate plainly a thinning out of the *Cynognathus* zone and Molteno Beds, and that overlap of the Stormberg Beds into older rocks which we know to have occurred in that direction. There is evidence of the occurrence of *Cisticephalus* and *Lystrosaurus* beds in Natal.

The map brings out clearly the fact that the Karroo rocks lie in a basin formed by two shallow synclines whose axes, running approximately east and west and north and south, meet in the Transkei, and that they dip at an extremely low angle to the east and the south respectively.

I have in connexion with this paper to thank the Trustees of the Percy Sladen Fund, who assisted me to visit South Africa, many farmers in Cape Colony too numerous to mention separately, and particularly my friends Dr. R. Broom and the Rev. J. H. Whaits, whose knowledge is invaluable.

III.—Periods of Dreikanter Formation in South Notts.

By Professor H. H. Swinnerton, D.Sc., F.G.S., F.Z.S.,
University College, Nottingham.

(PLATE XVI.)

IN the summer of 1911 I discovered numerous wind-worn stones in a gravel-pit near to Ramsdale, and situated at the side of the Old North Road 6 miles out of Nottingham. Samples of these were exhibited at the Geological Society's conversazione in 1912. During the next few months a trench for the water-main from the Derwent valley to Nottingham was opened along this road, and passed for a distance of over a mile through similar gravels, which in one place were at least 10 feet thick. Throughout this distance 'dreikanter' were common in the top 18 inches of soil and subsoil.

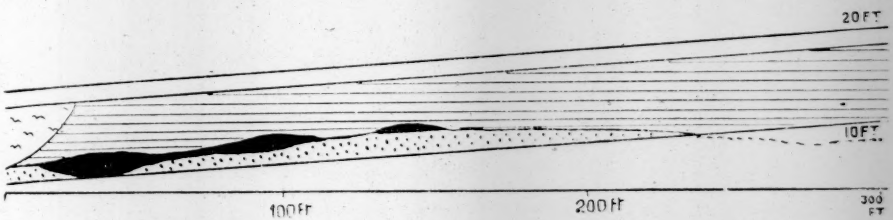
These wind-worn stones varied in size from small boulders 8 inches long to small pebbles. The majority were of quartzite and had assumed those forms usually associated with the term 'dreikanter'. Pebbles of less homogeneous constitution, such as grit, vein quartz, and various igneous rocks, were not as a rule facetted, but had that wavy, pitted, or undercut type of polished surface which is the characteristic effect of the sand-blast action of the wind and of insolation.

Further investigation shows that these wind-worn stones are not confined to the locality of Ramsdale, but are widely distributed over the whole district, on both Keuper and Bunter outcrops, from beyond Oxton in the north to Wilford Hill and Clifton in the south. No

doubt future exploration will reveal their presence beyond these limits. They are most abundant in the soil of a sheet of gravelly drift which at Bestwood lies near the 400 ft. contour, but drops gradually towards the south and south-east. Similar gravels at Clifton and Wilford lie just above the 200 ft. contour. In any ploughed field situated on this sheet one may reasonably expect to collect a basketful of 'dreikanter' in the course of a short search.

The pebbles which have been worn are derived for the most part from the Bunter conglomerate, but the question naturally arises as to when they became wind-worn. In this connexion several periods suggest themselves, viz. Triassic times, late Pleistocene times, and quite recent times.

There seems to be no doubt that the prevailing climatic conditions in Britain during the Triassic period were such as to favour wind action, but of course locally these conditions were counteracted by others. Immediately around Nottingham, for example, the Bunter conglomerate exhibits all the characteristics of a rapidly formed deltaic deposit. It is not surprising, therefore, that though this formation has been subjected to assiduous search it has not yet yielded indubitable wind-worn stones. After deposition had ceased, however, its surface seems to have been vigorously swept by winds.



Section made from a portion of the sewer trench opened along Arnot Hill Road. Dotted area, Bunter Conglomerate. Black area, 'dreikanter'-bearing gravels. Lined area, plastic clay at the base of the Keuper Waterstones. Other areas, soil, subsoil, and alluvium.

This is indicated by observations made during the opening of a sewer trench along Hallam's Lane (now Arnot Hill Road), which leads from Arnold to Arnot Hill. My attention was called to the trench by Mr. R. E. Clarke, the surveyor for the Arnold District Council, who had been struck by the peculiar subsoils which were being entered.

The trench ran slightly obliquely to the strike of the Keuper, and for 70 yards its floor lay in the substance or on the surface of the Bunter, whilst its sides were made up of the bottom beds of the Keuper Waterstones (Pl. XVI, Fig. 1). The lowest of these was a plastic clay, 3 feet thick and of deep-red colour, in its unweathered portions. The surface of the Bunter conglomerate upon which it rested can only be described as wind-swept (Pl. XVI, Fig. 2), for many pebbles projected more or less completely above the surface, others rested loosely upon it, and all, in striking contrast to the typically water-worn form of those still embedded in the conglomerate, showed clear signs of wind erosion.

Throughout 40 yards of the section the loose pebbles were so numerous as to form lenticular accumulations of coarse gravel, which at one point swelled out to a thickness of 2½ feet. The only portions of the Bunter conglomerate which can be compared with these are the pockets of pebbles that occur here and there at the bottom of the channels, which give the rock its current-bedded appearance. One of these pockets cropped out at the wind-swept surface and produced a slight tump which was completely covered by the gravel. Even in these pebbly portions of the Bunter sand fills up the spaces between the pebbles, all of which are rounded. In the gravels, on the other hand, sandy matrix was absent and wind-worn and facetted stones were common (Pl. XVI, Fig. 3, *f*, *g*, *h*, *i*). Moreover, the line of separation between the gravel and the underlying Bunter was perfectly defined. There can be no doubt, therefore, that these 'dreikanter'-bearing gravels were laid down under very different conditions from those which accompanied the formation of Bunter deposits, and that they must have been formed after the latter had been subjected to the action of aerial denudation for some time.

Nor is there any question of the gravel having been transported into this position by currents of water, for the angles between the facets show no signs of having been blunted by rolling; on the other hand, they are buried under a very fine Keuper clay which could only have been laid down in tranquil water.

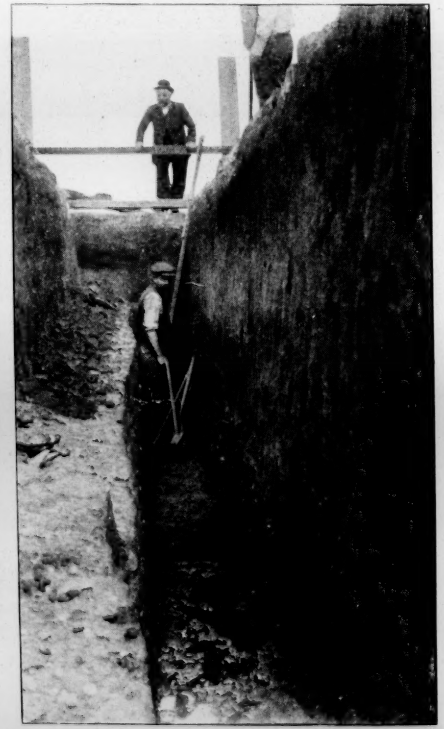
Confirmation of the occurrence of this episode in the history of the Trias of South Notts is forthcoming from the sand-pits at Dale Abbey, which lies just beyond the western county boundary. There the Bunter-like sandstone, which lies directly upon the Coal-measures, yields typical 'dreikanter'. For reasons which will be given in a later paper there is good ground for suspecting that these beds really belong to the same level as the 'dreikanter' gravels of Arnot Hill.

These Triassic wind-worn or wind-accumulated deposits are too discontinuous and limited in extent to account for even a fraction of the facetted and allied pebbles found in the drift. Whilst, therefore, a few may come from this source, the main mass of them must have been shaped by post-Glacial agencies.

To-day, when the wind is blowing over the Bunter outcrop the dust and sand raised from the landscape gives the effect of advancing cavalry. Drifts of sand 3 or 4 feet deep accumulate on the lee side of the hedges, and it is part of the ordinary duty of the farm labourer to redistribute the sand thus displaced by the wind. Such facts as these tempt one to believe that even up to the time when these lands were first enclosed for cultivation, 'dreikanter' were being carved. The fact that they seem to be confined to the top 18 inches of soil might be taken to point the same way. Nevertheless, certain phenomena associated with other gravels than those already mentioned seem to limit the main period of effective wind action to late Pleistocene times.

In the vale of the Trent near Nottingham there are two sets of gravels: the younger, which carpets the floor of the vale, everywhere underlies the alluvium, and occasionally rises up into low flat-topped

1



Excavation through base of Keuper.

2

Wind-swept surface of Bunter.

3

Facetted stones from Drift and Trias.

mounds a few feet above the flood-levels; the older, which occupies terraces about 20 feet higher and fringe the vale at Beeston, Gamston, and elsewhere. The ploughed fields and gravel-pits situated on these terraces all yield facetted and other types of wind-worn stones, but though the surface of the younger gravels have been carefully searched, not a single one has been found. It seems, therefore, that for a while the Trent, probably much swollen by the melting snows and ice of late Pleistocene times, cut out its trench-like valley with great rapidity, but that when it reached the level of the older gravel terraces it paused in the process. During this long pause climatic conditions were such as to favour effective wind-action. Subsequently the river deepened its vale a little more, but since that time this action has been reduced to a minimum.

EXPLANATION OF PLATE XVI.

FIG. 1. View of the Arnot Hill sewer trench. The boundary between the clay and the thickest part of the dreikanter-bearing gravels is indicated by the top of the workman's tool.

.. 2. Wind-swept surface of Bunter. Top right-hand portion shows the projecting and loose pebbles. On the left, and below, some clay is seen still adhering to the surface and surrounding the projecting pebbles.

.. 3. Facetted stones. Those marked *a*, *b*, *c*, *d*, *e* were collected from various points on the sheet of gravelly drift. Those marked *f*, *g*, *h*, *i* were collected from the Triassic 'dreikanter' gravel of Arnot Hill.

IV.—Note on the Source of the Pebbles of the Bunter Pebble-beds of the English Midlands.

By C. A. Matley, D.Sc., F.G.S.

THE subject of the derivation of the materials which form the Bunter Pebble-beds has given rise to wide differences of opinion and to a voluminous literature. These it is not my intention to recapitulate, as an excellent summary of the subject will be found in Mr. O. H. Shrubsole's paper of 1903.[1] Mr. Shrubsole then gathered together the known evidence, added some new facts of his own, and came to the conclusion that the Midland Bunter pebbles were brought from a southerly direction. This opinion may be said to have held the field until recently, when the question was again taken up by Mr. Jukes-Browne in the third edition of *The Building of the British Isles* (1911). After reviewing the whole evidence and taking into consideration the results of an investigation by Mr. E. C. Martin, which tended to show that the direction of transportation in Somersetshire in Bunter times was towards the south, Mr. Jukes-Browne abandoned the view he had taken in the second edition (1892) of that work, and now, adopting in the main the conclusions of Professor Bonney, considers that the bulk of the pebbles of the

[1] "On the Probable Source of some of the Pebbles of the Triassic Pebble-beds of South Devon and of the Midland Counties": Q.J.G.S., vol. lix, pp. 311–31, 1903.

Midland Bunter came from the north-west, though he agrees that the fossiliferous quartzite pebbles could not have come from that direction, and he suggests for these a south-easterly derivation (Suffolk).

The question cannot, however, be considered as finally settled by this pronouncement, and I am tempted to re-open it in the hope of stimulating further investigation. I also urge a fuller consideration of Mr. Shrubsole's arguments, which do not appear to have been sufficiently appreciated.

Although hitherto refraining from the discussion of this problem[1] I have for over thirty years taken an interest in it. While yet a schoolboy I followed the example of P. B. Brodie, W. Jerome Harrison, and others by collecting the fossiliferous quartzite pebbles of Bunter origin found in the Drift of the Birmingham district. At a later date, when engaged in mapping the Keuper Marls of Warwickshire, I turned my attention again to the associated Drift, from which I got together a further collection of the fossiliferous, as well as of non-fossiliferous pebbles. It was not till last winter, however, that I was able to take up their examination in detail, and it so happened that I had not proceeded far with the work when I had to leave it owing to taking up an appointment in India at very short notice. As I shall not be able to resume this work for at least two years, it seems convenient to give a short account of the evidence on which I came years ago to conclusions almost completely in accord with those of Mr. Shrubsole, and which I have as yet seen no good ground for modifying.

A large proportion of the pebbles which occur so abundantly in the Drift of the Birmingham district have unquestionably been derived from Bunter beds, and though in theory it appears unsafe to frame arguments as to the Bunter deposits from material found in the Drift, the worker who is acquainted with both sets of deposits has usually no hesitation in deciding that certain pebbles in the Drift are of Triassic origin. I should, of course, have preferred to deal with the Bunter pebbles at first hand, but my geological work happened to lie on Keuper Marls, and the investigation of the Bunter material found in the Drift of that area was only pursued as a side issue to my study of the Drift.

Fossiliferous quartzite pebbles are distinctly rare; as Mr. W. J. Harrison has remarked, probably not more than one pebble in a thousand is fossiliferous. Those containing worm-burrows are most abundant, and my collection contains about fifty such pebbles (of which two came direct from the Bunter Conglomerate), though I could have obtained probably twice that number had I collected every specimen I found. These burrows are all straight sub-cylindrical tubes which can be grouped roughly into about four types, according to diameter and amount of corrugation. The differences may not, however, be specific, but be dependent merely upon the amount of

[1] Except in the discussion on Dr. A. E. Salter's paper "On the occurrence of Pebbles of Schorl-rock from the South-west of England in the Drift Deposits of Southern and Eastern England": Q.J.G.S., vol. lv, pp. 220–3, 1899.

growth of the individual worms. No other organisms occur in these pebbles, the age of which is uncertain, but one of the types is certainly the *Tigillites dufresnoyi*, Rou. (*Trachyderma serrata*, Salt.) of the Grès de May.

Next in abundance come the Brachiopoda, preserved in about seventy pebbles. A preliminary examination, which was all I was able to give them, showed that the species agreed very closely with those found in the Budleigh Salterton pebbles and that they yielded the three faunas already known to occur both in the Devonshire beds and in other collections of Bunter pebbles from the Midlands. The three faunas are those of (1) the Grès Armoricain, (2) the Grès de May, and (3) the Devonian, and the typical species are distinctly southern forms that are not found in situ nearer than the North of France and the South of England. The Grès de May is the most abundantly represented of the three, *Orthis* (*Dalmanella*) *budleighensis*, Dav., being by far the commonest species, as over thirty pebbles contain this form and in a number of them the specimens occur gregariously. Other *Orthides* in the collection probably also belong to this formation, as, for example, *Orthis* cf. *berthoisi*, var. *erratica* and some other species, not yet determined, which seem to be of approximately Bala age.

The Grès Armoricain is well represented by *Lingula lesueuri*, Rou. (about ten examples), by fewer examples of *Lingula hawkei*, and by one specimen which is probably *Dinobolus brimonti*. Some small Lingulidæ have also been obtained, which may be immature examples of one or both of the above-mentioned species.

The Devonian forms seem to be rarer, but my collection contains several specimens of Spirifer, of which some seem to be identical with the form recorded by Davidson as *Spirifer verneuili*, and it is associated with *Camarotœchia* cf. *elliptica*, Schnur. The other Spirifers have not yet been fully studied.

In addition to the above there are a number of Lamellibranchs, a few pygidia and other fragments of Trilobites, and occasional Echinoderm-remains, etc. Though they have not yet been examined, they will no doubt confirm and extend the results yielded by the Brachiopods. In order that they may be available for future research I have handed over the whole collection to the Geological Survey Museum, Jermyn Street.

The palæontological evidence must, I think, be accepted as conclusive that the quartzite and quartzose-sandstone pebbles containing these fossils came from some southerly point, though there is room for speculation as to whether they were derived from the area in which the fossils are to be found at the present day, viz. Normandy and the region adjacent, or from some tract in the South or South-East of England now buried beneath Mesozoic or Cainozoic deposits. This being so, why should not the great bulk of the associated non-fossiliferous pebbles, which cannot be distinguished externally by shape, size, colour, or texture from the fossiliferous ones, have come from the same area? I have seen something of the Old Red Conglomerates of Scotland, and recognize the striking resemblance that their contained quartzite pebbles bear (except as regards fossils) to

those of the Midland Bunter; but the fact that the Midland Bunter pebbles decrease rapidly in size and number as the beds are followed to the north-west and north-east offers so grave an objection to the theory of a Scottish origin, and on the other hand the palæontological and lithological evidence so strongly supports the view of a southern source for these quartzites, that it seems to me the former theory should definitely give place to the latter.

There is also another line of lithological evidence which supports the 'southern' theory. Occurring as a characteristic though minor element in the Bunter Conglomerate and as derived pebbles in the Drift are some pebbles of schorl-bearing rocks. The majority are tourmalinized quartzites and grits, some are of schorlaceous breccia, while a few are of schorlaceous granite, the latter being ordinarily too decomposed to be of petrographical value. The presence of such rocks has long been known; Mr. S. G. Perceval collected them from the Drift and Mr. T. H. Waller described them microscopically many years ago, while Professor Bonney did so from the Bunter later; but their importance as bearing on the general problem of the origin of the Bunter pebble-bed does not seem to have been fully recognized. Although tourmaline-bearing rocks are known in other parts of the British Isles they occur most characteristically and in greatest force in Devon and Cornwall, and the types found as pebbles can be well matched there. To test this fact I selected two pebbles from the Drift near Birmingham, one being a schorl-breccia in which Mr. G. Barrow thought he recognized a typical fragment of Cornish 'Killas' and the other a pebble of exceptionally fresh schorlaceous granite. They are now in the Jermyn Street Collection, and Dr. H. H. Thomas has been good enough to allow me to make use of the following notes of his microscopical examination of thin slices made from them:—

E. 9553. South of California, near Harborne. Breccia of pale fine-grained rock in dark-grey to black matrix. Schorlaceous breccia. The fragments are mainly of fine-grained quartzose sediments and occasionally of felsite with fluxion-structure. The matrix consists of a mass of the finest acicular tourmaline of blue-green colour. The tourmalinization of the rock as a whole appears to have been accomplished after the brecciation, for the process has affected the larger fragments wherever they contained any aluminous material.

E. 9554. From a pebble-heap near Kent Cottages, Sheldon, near Birmingham. Schorlaceous granite. The rock is composed of orthoclase, quartz, and tourmaline. The slightly decomposed orthoclase and quartz are intergrown occasionally with an approach to micrographic structure. The tourmaline of the larger crystals is brown, but these crystals invariably have an outer blue layer. The smaller crystals and needles of this mineral are of a blue colour as in luxullianite. The tourmaline occurs alike in the quartz and in the orthoclase.

Dr. Thomas adds that "It is hard to assign any other source to these pebbles than the West of England, for in that region alone can the types be matched with any degree of closeness".

From the above evidence the principal source of the Midland Bunter pebbles seems to me to lie in an area embracing the South-West of England and the North-West corner of France. Until borings yield some positive evidence (which, so far as I know, they

have not yet done) that the buried Palæozoic rocks of the South-East and East of England contain the right rock-types and the right fossils I would not give those buried areas special consideration.[1] If the objection be made that the geographical conditions of Bunter time were such that a rock barrier prevented the flow of these materials from the south-west into the Midlands, as indicated in Mr. Jukes-Browne's map (op. cit., fig. 34), then the evidence for the complete barrier ought to be carefully collected and the impossibility of a connexion be clearly proved. I suggest that one of the tributary streams that carried the Bunter gravels may have followed the line of the present Bristol Channel, a course which would provide a likely source of the Carboniferous Limestone (often silicified), Chert, Llandovery Sandstones,[2] etc., as well as of the schorl-rocks, which occur in the Midland Bunter.

There must have been some local contributions to the Midland Triassic pebbles; and local quartzites like those of the Lickey and Hartshill and some of the rock-fragments in the Permian breccia probably played some part, though a minor part, in contributing to the mass of these materials.[3]

In spite of much excellent work that has already been done, much remains to be accomplished. For instance, among the rarer pebbles to be met with in the Bunter Conglomerate are various examples of hard rocks, apparently of great antiquity, which it has not been my experience to meet in situ in the field or to see in museum collections of British rocks. A careful collection of these rarer and special types, a record of the distribution of each type, and a correlation with similar rocks exposed at the present day would probably lead up to valuable results. In seeking for correlations the rocks of Brittany should not be overlooked.

I regret to have had to present this paper while so much of my collected material remains unstudied, but the circumstances are exceptional, and, as already stated, I wish to stimulate further research into this important and interesting subject.

I have had to write the above without access to books of reference, maps, or specimens, so that apart from some notes I have had to rely on memory for many statements.

[1] It is true that *Spirifer verneuili* was found in the Tottenham Court Road boring, but it is a widely distributed Devonian fossil, and it occurred there in a matrix altogether different from the Bunter pebble type.

[2] I have not seen the specimens, but I would be inclined to eliminate from the published lists of fossils found in Drift pebbles and ascribed to the Bunter those that indicate a Llandovery age. For instance, *Stricklandinia lirata* in W. J. Harrison's list is found in the Rubery Sandstone of the Lickey Hills. This sandstone is made up of the waste of the Lickey Quartzite, on which it rests unconformably, and it sometimes simulates in texture and appearance the older rock. Specimens from this source may have come direct into the Drift without ever having become Bunter pebbles, and in either case they are of local origin.

[3] The less-rounded quartzite pebbles of the Lower Keuper basement-beds of the Midlands suggest a derivation from local quartzites. The materials of these beds, as Mr. Harrison remarked in 1882, deserve careful and detailed study.

V.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATES XVIII AND XIX.)[1]

Introduction.

THE Speeton Clay of Yorkshire is of considerable interest, as it is the chief marine representative of the Lower Cretaceous formations in England. It has been the subject of important papers by Professor J. W. Judd, F.R.S.,[2] and Mr. G. W. Lamplugh, F.R.S.,[3] while the palæontology of the Cephalopoda and Lamellibranchiata has been respectively worked out by Professor A. P. Pavlow[4] and Mr. H. Woods.[5] Mr. C. G. Danford[6] has also contributed to our knowledge of the beds. The Microzoa, however, have never been examined, and the present paper gives the results of an investigation of the Foraminifera of the deposit.

I am indebted to Mr. Lamplugh for the suggestion that I should undertake the work, and to him and Mr. C. G. Danford for the specimens of clay which have been examined. The condition of the cliffs at Speeton is such that many horizons of the clay are only rarely exposed, as, for example, after storms, so that it is very difficult to obtain specimens of these subdivisions. Mr. Danford has known the Speeton cliffs for many years and has that special knowledge of the various beds without which it would be impossible to obtain specimens of any value for zonal work. My thanks are also due to Mr. F. Chapman for his advice on many knotty points and to Dr. F. L. Kitchin and Mr. C. D. Sherborn for valuable suggestions.

Literature.—There is practically no literature relating to the Foraminifera of the Speeton Clay of Yorkshire. Mr. Lamplugh, in his earlier paper, refers to the presence of large and well-preserved Foraminifera in the *Echinospatangus* bed (C_3), and notes that they are "found cemented together in small hard pellets not often larger than shot-corns" (op. cit., p. 596). In his lists of fossils (pp. 599, 602) he records the presence of Foraminifera in D_1, C_{11-1}, and B.

The late Rupert Jones inserts *Pulvinulina caracolla* (Roemer) from the Speeton Clay in his *Catalogue of the Fossil Foraminifera in the*

[1] [Plates XVIII and XIX have been unavoidably delayed and will appear with the subsequent portion of this paper.—Ed.]

[2] J. W. Judd, "On the Speeton Clay": Q.J.G.S., vol. xxiv, pp. 218–50, 1868. "Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, with Notes on their Relations to the Beds of the same age throughout Northern Europe": Q.J.G.S., vol. xxiv, pp. 326–48, 1868.

[3] G. W. Lamplugh, "On the Subdivisions of the Speeton Clay": Q.J.G.S., vol. xlv, pp. 575–618, 1889. "On the Speeton Series in Yorkshire and Lincolnshire": Q.J.G.S., vol. lii, pp. 179–220, 1896.

[4] In A. Pavlow & G. W. Lamplugh, "Les Argiles de Specton et leur Équivalents": Bull. Soc. Imp. des Naturalistes de Moscou, N.S., vol. v, pp. 181–276, 455–570, 1891–2.

[5] H. Woods, A Monograph of the Cretaceous Lamellibranchiata of England (Pal. Soc.), 1899–1913.

[6] C. G. Danford, "Notes on the Belemnites of the Speeton Clay": Trans. Hull Geol. Soc., vol. vi, pt. iii, pp. 1–18 (plates), 1905 [1906]. Also "Notes on the Speeton Ammonites": Proc. Yorks Geol. Soc., vol. xvi, pt. i, pp. 101–14 (plates), 1906 [1907]; and other papers.

Collection of the British Museum (Natural History), 1882, p. 9. Specimens of this species, named by Rupert Jones, are in the British Museum and in the Museum of Practical Geology.

The Foraminifera of the Red Chalk, which lies above the Speeton Clay, have been described by Messrs. H. W. Burrows, C. D. Sherborn, and G. Bailey in "The Foraminifera of the Red Chalk of Yorkshire, Norfolk, and Lincolnshire", Journ. Roy. Micr. Soc., 1890, pp. 549–66, pls. viii–xi.

Foraminifera from rocks of approximately the same age as the Speeton Clay have been described by (1) A. E. Reuss in his paper "Die Foraminiferen der norddeutschen Hils und Gault", Sitzungsber. k. Akad. Wiss. Wien, vol. xlvi, Abth. i, pp. 5–100, pls. i–xiii, 1862 (1863). (2) J. Cornuel, "Description de nouveaux fossiles microscopiques du terrain crétacé inférieur du département de la Haute-Marne," Mém. Soc. géol. France, sér. II, vol. iii, pp. 241–63, pls. iii, iv, 1848. (3) F. Chapman, "The Bargate Beds of Surrey and their Microscopic Contents," Q.J.G.S., vol. l, pp. 677–730, pls. xxxiii, xxxiv, 1894. (4) F. Chapman, "The Foraminifera of the Gault of Folkestone," pts. i–x, in Journ. Roy. Micr. Soc., 1891–8. (5) G. Berthelin, "Mémoire sur les Foraminiféres fossils de l'Etage Albien de Montcley (Doubs)," Mém. Soc. géol. France, sér. III, vol. i, No. 5, pp. 1–84, pls. xxiv–vii, 1880.

Treatment of Material.—The specimens examined were small, usually from 1 to 2 cubic inches, so that the list of Foraminifera cannot be regarded as exhaustive, but it is clear that there are not more than four horizons in the zones C, D, E, and F (see pp. 218, 219) which are likely to repay a further search.

The dry clay was broken into small pieces about the size of a pea, and these fragments were heated gently over a Bunsen burner and dropped whilst hot into cold water. After standing for a short time the sediment was washed free from fine mud and the residue dried and passed through a sieve. The sediment was then passed through, first, coarse, and then through fine muslin, and the different residues were examined under the microscope for Foraminifera. The great majority of the forms were obtained from that part which had passed through coarse muslin but was stopped by fine muslin. One or two specimens of hard shale refused to break up under this treatment, and these were examined in minute fragments under the microscope.

The results of the investigation are somewhat disappointing. The specimens of Speeton Clay examined, except from a few horizons, are almost without Microzoa, and those found have, as a rule, few special characteristics.

Stratigraphical Distribution.—The beds were divided by Mr. Lamplugh[1] into the following main divisions in downward succession:—

A. Marls with *Belemnites minimus*, List., and allies.
B. Zone of *B. semicanaliculatus* (?) and allies.
C. Zone of *B. jaculum*, Phil., and varieties.
D. Zone of *B. lateralis*, Phil., and varieties.
E. Coprolitic seam.
F. Bituminous shales with varieties of *B. Owenii*, Pratt.

[1] Q.J.G.S., vol. xlv, p. 581, 1889.

Professor A. P. Pavlow [1] correlates these divisions with those of the Continent as follows:—

[Aptien] = B.
Barrémien = C_1–C_1 [an evident misprint for C_1–C_7].
Hauterivien = C_8–C_{11}.
Valengien = D_1, lower part, D_3.
Upper Tithonian = D_4–D_8.

No Foraminifera whatever were found in divisions F and E (Upper Kimeridge [2]). I have not any specimens from A, and in the case of B only from the basal bed. Theoretically D should have proved the most interesting, as doubts have been expressed whether this division should be regarded as Jurassic or Cretaceous, but Foraminifera are comparatively rare in D. However, some evidence has been obtained and will be referred to later. Of the eight subdivisions of D, Foraminifera have been found in D_2, D_3, and D_6 only.

In C_1, which is certainly of Lower Cretaceous age, Foraminifera were found in C_1, C_2, C_3, C_7, C_9, and C_{10} of the eleven subdivisions, but I have no material from C_4, C_5, and C_6. In B the base was alone examined, and proved to be one of the best horizons for Microzoa. I have not found specimens from any bed higher than the base of B.

The information obtained is summarized in the following notes on the divisions examined, commencing with the lowest bed.

F. Upper Kimeridge. The extreme top of F is a black shale which is most difficult to break up for the purpose of separating any Microzoa that may be present. A few minute white spherical bodies may be the initial cells of Foraminifera.

D_8. The base of D_8 contains selenite, an indication that any calcareous Microzoa have been destroyed. The horizon is interesting mineralogically as it contains grains of garnet, kyanite, and other heavy minerals, together with quartz-sand and a few grains of phosphate.

D_7 (the blue band). Only traces of shells remain, the rest have undergone decomposition.

D_6 (lower part). Crystals of selenite indicate destruction of calcareous fossils.

D (middle part). A few Foraminifera and Ostracoda were found. The former comprise *Nodosaria* sp., *Marginulina jonesi*, Reuss, *Rhabdogonium insigne*, Reuss, *Vaginulina* sp. (fragment), *Cristellaria acutauricularis* (Fichtel & Moll), *C. cultrata* (Montfort), *C. gaultina*, Berthelin, *C. rotulata* (Lamarck), *Pulvinulina caracolla* (Roemer), glauconite casts of Cristellarians, and an arenaceous form. There are a few grains of a transparent cubic mineral which is probably garnet, and grains of coloured quartz.

[1] "On the Classification of the Strata between the Kimeridgian and Aptian": Q.J.G.S., vol. lii, pp. 542–55, pl. xxvii, 1896.

[2] A recent paper by Dr. Hans Salfeld (Q.J.G.S., vol. lxix, pp. 423–32, pls. xli, xlii, 1913) indicates that Portlandian beds may be present in this division of the Speeton Clay.

D_6 (upper part). Fragments of shells and crystals of selenite.

D_5. No Foraminifera.

D_4. Small rod-like bodies, apparently glauconite casts. Quartz grains.

D_3. Small rod-like bodies as in D_4 and occasionally a minute nodule of pyrites. Foraminifera are rare and comprise an arenaceous form and *Cristellaria rotulata* (Lamarck).

D_2 (base). Some glauconite grains. A fair number of Foraminifera, but the specimens are usually imperfect. Arenaceous forms are more frequent in this than in any other zone examined. For the most part they are very fragile and fall to pieces readily, and it is probably this fragile character that causes them to be relatively rare in the Speeton Clay.

The following are the Foraminifera found and determined: *Bulimina* sp., *Cristellaria cultrata*? (Montfort), *Pulvinulina caracolla* (Roemer).

A number of small, nearly circular grains resemble arenaceous Foraminifera, but examination in oil of cloves shows that there is a radial crystalline structure and the grains appear to be concretions. Mr. H. H. Thomas has kindly examined them for me and finds that they are composed of gypsum.

D_2 (top). Some glauconite grains and a few poor specimens of Foraminifera.

C_{11}. Abundant grains of glauconite, some, at least, being casts of Foraminifera.

C_{10}. Foraminifera moderately abundant. The species are *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *Nodosaria* (*Glandulina*) *lævigata*, var. *strobilus*, Reuss, *Cristellaria gibba*, d'Orb. There are also present Ostracods, and grains of a red mineral which is probably garnet.

C_9. Foraminifera not numerous. They are *Lagena apiculata* (?), Reuss (broken), and *Cristellaria rotulata* (Lamarck). In addition there are fragments which appear to be *Inoceramus* prisms. As *Inoceramus venustulus*, Bean, is abundant at this horizon, it is very probable that the fragments are derived from this mollusc.

C_8 (?). There is some doubt as to the horizon from which the specimen was collected. In any case no recognizable Foraminifera were obtained.

C_7. A fair number of specimens of *Pulvinulina caracolla* (Roemer) were obtained, all broken.

C_3 (upper part)? I have not been able to obtain specimens of the strata between C_7 and the upper part of C_3, and the specimen from the latter horizon is not free from doubt as regards its exact position. It contains grains of glauconite and a considerable number of Foraminifera. These are chiefly specimens of *Pulvinulina caracolla* (Roemer), and are usually broken and filled with glauconite. *Cristellaria gibba*, d'Orb., *C. rotulata* (Lamarck), and *Pulvinulina lamplughi*, sp. nov., also occur, and these latter forms are not broken.

C_2 (upper part)? Here, again, there is some doubt as to the exact horizon of the material, and it is particularly unfortunate, since this

bed is one of the most prolific in Foraminifera. Specimens are very numerous, but the great majority belong to a single species, *Pulvinulina caracolla* (Roemer). Although the specimens are often broken, they are on the whole better preserved than in C_3 (?). The species are: *Reophax scorpiurus*, Montfort, *Ammodiscus gordialis* (Jones & Parker), *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *L. apiculata*, var. *danfordi*, var. nov., *L. lævis* (Montagu), *Nodosaria* (*Dentalina*) *fontanessi*, Berthelin, *N.* (*D.*) *lorneiana*, d'Orb., *N.* (*D.*) *communis*, d'Orb., *N.* (*D.*) *roemeri*, Neugeboren, *Frondicularia gaultina* (?), Reuss, *Marginulina linearis*, Reuss, *M. jonesi*, Reuss, *M. debilis*, Berthelin, *Cristellaria gibba*, d'Orb., *C. chapmani*, sp. nov., *C. crepidula* (Fichtel & Moll), *C. turgidula*, Reuss, *C. rotulata* (Lamarck), *Polymorphina fusiformis*, Roemer, *P. problema*, d'Orb., *Pulvinulina repanda* (Fichtel & Moll), *P. caracolla* (Roemer), and *P. lamplughi*, sp. nov.

A minute *Dentalium*, minute spines of Echinoids, and a few Ostracods were also found. The material contains a little glauconite. All the particles, except the finest, are well rounded, but the Foraminifera, other than *P. caracolla*, are well preserved.

C_1. Many grains of glauconite, some of them obviously internal casts of Foraminifera. A moderate number of Foraminifera were found, almost all of them Cristellarians. The species are: *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *Cristellaria acutauricularis* (Fichtel & Moll), *C. turgidula*, Reuss, and *C. rotulata* (Lamarck).

B (base *a*). Three specimens of the basement beds of B were examined, called *a*, *b*, and *c*, of which *a* is the lowest. This last material yielded a few decomposed Foraminifera, one being a rotaline form. It is probable that fossils were originally present in fair number, but they have been destroyed by the alteration of the calcite into gypsum. *Inoceramus* prisms were noted.

B (base *b*). Abundant glauconite grains, some of which are obviously the internal casts of Foraminifera. In addition the following shells were found: *Nodosaria hispida*, d'Orb., *Marginulina jonesi*, Reuss, *Cristellaria cephalotes*, Reuss, *C. rotulata* (Lamarck), *Pulvinulina caracolla* (Roemer).

B (base *c*). This horizon is perhaps the richest in Foraminifera of all those examined. In many of the specimens the shells are filled with glauconite and have been partly worn away. Under the microscope the material seems to be made up of small 'pebbles' of shale, and much of it may be derived from an older deposit. The majority of the individuals are young fry. The species found are: *Haplophragmium latidorsatum* (Bornemann), *Textularia agglutinans*, d'Orb., *Bigenerina nodosaria*, d'Orb., *Gaudryina filiformis*, Berthelin, *Lagena apiculata*, Reuss, *L. lævis* (Montagu), *Nodosaria calomorpha*, Reuss, *N.* (*Dentalium*) *siliqua* (?), Reuss, *N.* (*D.*) *legumen*, Reuss, *Marginulina glabra*, d'Orb., *Cristellaria gracillissima*, Reuss, *C. acutauricularis* (Fichtel & Moll), *C. scitula*, Berthelin, *C. chapmani*, sp. nov., *C. crepidula* (Fichtel & Moll), *C. gaultina*, Berthelin, *C. sternalis*, Berthelin, *C. orbiculata* (Roemer), *C. rotulata* (Lamarck), *Polymorphina fusiformis*, Roemer, *Pulvinulina repanda* (Fichtel and Moll), *P. caracolla* (Roemer), *P. lamplughi*, sp. nov.

Family LITUOLIDÆ.

Sub-family LITUOLINÆ.

Reophax, Montfort.

Reophax scorpiurus, Montfort. (Pl. XVIII, Fig. 1.)

Reophax scorpiurus, Montfort, 1808 : Conchyl. Système, vol. i, p. 330, 83e genre.
Nodosaria agglutinans, Terquem, 1870 : Mém. Acad. Imp. Metz, 1869-70, p. 252, pl. xxix, fig. 18.
Reophax helvetica, Haeusler, 1883 : Q.J.G.S., vol. xxxix, p. 27, pl. ii, figs. 8–10.

Remarks.—Two specimens, differing considerably in size, seem to belong to this species, although the larger one resembles somewhat *R. piluliferæ*, Brady (Chall. Rep., p. 292, pl. xxx, figs. 18–20). *R. scorpiurus* is known from the Swiss Jurassic (Haeusler), the Oolite of Fontoy, Moselle (Terquem), and the post-Tertiary of Norway (Crosskey & Robertson). Chapman records it from the Folkestone Gault. At present it is a very common cosmopolitan species at from 3 to 3,960 fathoms (Brady). *R. piluliferæ*, however, to which the larger specimen has affinities, is confined to deep water, having been found from 800 to 2,435 fathoms (Brady, Chall. Rep.).

Horizon.—Found in Upper C_2. Two specimens.

Haplophragmium, Reuss.

Haplophragmium latidorsatum (Bornemann). (Pl. XVIII, Fig. 3.)

Nonionina latidorsata, Bornemann, 1855 : Zeitschr. d. deutsch. geol. Gesell., vol. vii, p. 339, pl. xvi, figs. 4*a*, *b*.
Haplophragmium crassum, Reuss, 1867 : Sitzungsb. d. k. Ak. Wiss. Wien, vol. lv, p. 46, pl. i, figs. 1, 2.
H. rotundidorsatum, Hantken, 1875 : Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, p. 12, pl. i, fig. 2.

Remarks.—The species has been recorded by Bornemann from the Septaria-clay of Hermsdorf, near Berlin, by Reuss, from the Salt-clay of Wielizka in Galicia, and by Hantken from the Clavulina-Szaboi Beds of Hungary, all of which are of Middle Tertiary age. Chapman records it from the Folkestone Gault, and it is at present a deep-sea form according to Brady.

Horizon.—One specimen from B base *c* (unfortunately lost after drawing).

Sub-family TROCHAMMININÆ.

Ammodiscus, Reuss.

Ammodiscus gordialis (Jones & Parker). (Pl. XVIII, Fig. 5.)

Trochammina gordialis, Brady, 1876 : Monogr. Carb. and Perm. Foram., p. 77, pl. iii, figs. 1–3.

Remarks.—The species is known from the Carboniferous rocks of Great Britain and Belgium, and from the Permian of Northern England, and it is still living. Brady (Chall. Rep.) records its presence in seas varying in depth from 50 to over 2,000 fathoms.

Horizon.—Found in Upper C_2. One specimen.

Family TEXTULARIIDÆ.

Sub-family TEXTULARIINÆ.

TEXTULARIA, Defrance.

Textularia agglutinans, d'Orb.

Textularia agglutinans, d'Orbigny, 1839 : Foram. Cuba, p. 136, pl. i, figs. 17, 18, 32–4.

Remarks.—The species is recorded from the Folkestone Gault (Chapman), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), and is still living at widely different depths (Brady).

Horizon.—A simple specimen was found in B base *c* and lost.

BIGENERINA, d'Orbigny.

Bigenerina nodosaria, ? d'Orb. (Pl. XVIII, Fig. 2.)

Bigenerina nodosaria, d'Orbigny, 1827 : Ann. Sci. Nat., vol. vii, p. 261, No. 1, pl. xi, figs. 9–12 ; Modèle No. 57.

B. nodosaria, Terrigi, 1880 : Atti dell'Accad. Pontif., ann. xxxiii, p. 192, pl. ii, fig. 28.

B. nodosaria, Brady, 1884 : Chall. Rep., vol. ix, p. 369, pl. xliv, figs. 14–18.

Remarks.—The single specimen found has only two cells in the uniserial portion of the shell, and the arrangement of the initial cells is not clear, so that there is some doubt as to the determination. The species has been recorded in the Miocene of the Viennese Basin and of Malta (d'Orbigny, Parker & Jones), and in the later Tertiaries of North Germany (Roemer), Italy (Costa, Terrigi), and Spain (Parker & Jones). Brady states that it is common in the North Atlantic and is also found in the North Pacific at depths varying from 7 to 1,630 fathoms.

Horizon.—Found in B base *c*. One specimen.

GAUDRYINA d'Orbigny.

Gaudryina filiformis, Berthelin. (Pl. XVIII, Fig. 4.)

Gaudryina filiformis, Berthelin, 1880 : Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 25, pl. i, fig. 8.

G. filiformis, Wright, 1882 : Proc. Belfast Nat. Field Club, 1880–1, App., p. 180, pl. viii, figs. 3, 3*a*, *b*.

G. filiformis, Chapman, 1892 : Journ. Roy. Micr. Soc., p. 752, pl. xi, fig. 7.

Remarks.—The triserial commencement of this form is very small and difficult to make out. The species is known from the Gault of France (Berthelin) and of Folkestone (Chapman). It is still living, and has been recorded from shallow water by Wright, Balkwill, and Robertson, and by the *Challenger* Expedition from four stations at depths varying from 390 to 620 fathoms.

Horizon.—Found in B base *c*. Two specimens.

Sub-family BULIMINÆ.

BULIMINA, d'Orbigny.

Bulimina sp.

A broken and coarsely arenaceous specimen of this genus was found in D_2 (base).

(*To be continued.*)

NOTICES OF MEMOIRS.

A New Classification of Ore-deposits. By Dr. F. H. Hatch.

In his presidential address to the Institution of Mining and Metallurgy,[1] Dr. F. H. Hatch gave the following outline of a new classification of ore-deposits:—

Modern views on ore-genesis may be reduced to two principal lines of inquiry, the one dealing with the agent or vehicle, by which the metals have been collected, conveyed to, and deposited in the places where they are now found, and the other with the nature of the concentrates formed in the course of these processes.

Considering the latter first, ore-deposits are found to be either—

1. Igneous differentiates.
2. Cavity-fillings.
3. Metasomatic replacements.
4. Stratified or sedimentary deposits.
5. Residual deposits.

Of these, the sedimentary deposits comprise marine, lacustrine, and fluviatile accumulations, including placers.

Coming now to the agent or vehicle of ore-concentration, these are found to be—

(*a*) Molten magmas.
(*b*) Gases and vapours above their critical temperatures.
(*c*) Deep-seated waters, whether of magmatic or of meteoric origin.
(*d*) Vadose waters.
(*e*) Chemical and bacterial agents in lakes and seas.
(*f*) Mechanical agents, such as moving water and wind.

It is possible, by combining the facts elicited by these two lines of inquiry, to formulate a genetic scheme of classification. For example, cavity-filling may be due to igneous injection, to gases and vapours above their critical temperatures, to deep-seated waters, or to vadose waters; again, metasomatic replacement may be brought about by gases and vapours, by deep-seated waters, or by vadose waters. By arranging these two series of relationships in vertical and horizontal columns respectively, all the various types of ore-deposits are obtained at their intersections; and in this way the classification shown in the accompanying Table (pp. 224–5) is obtained.

"Considering the world-wide interest of England in the mining of precious metals throughout the world, it seems rather singular that so little attention is being given to ore-deposits by the geologists and engineers of that country. It is true that there are notable exceptions to this, but with English mining engineers working in the most remote parts of the world it seems as if their contributions to the science of ore-deposits is disproportionately small."[2]

[1] Delivered at the annual meeting of the Institution held at Burlington House on March 26.

[2] Lindgren, "Tendencies in the Study of Ore-deposits": Econ. Geol., vol. ii, p. 745, 1907.

CLASSIFICATION OF ORE-DEPOSITS.

Nature of Deposit.	Vehicle or Agent		
	(*a*) **Molten Magmas.**	(*b*) **Gases and Vapours** above their critical temperatures.	(*c*) **Deep-seated Waters,** whether of magmatic or meteoric origin.
1. Igneous Differentiates.	Certain massive iron and nickel ores associated with basic igneous intrusions (e.g. those of Sudbury in Ontario).		
2. Cavity-fillings.	Injected tin-ores (e.g. tin-pegmatites and tin-elvans on the margin of granite intrusions).	Pneumatolytic cavity - fillings (e.g. tin quartz veins).	Hydato-genetic cavity - fillings (many fissure veins).
3. Metasomatic Replacements.		Pneumatolytic replacements (e.g. tin-greisens and many contact-deposits).	Hydato-genetic replacements (many veins and massive deposits, also the Rand Banket).
4. Stratified Deposits.			Possibly some sedimentary deposits in which the cementing materials are ores of the metals.
5. Residual Deposits.			

By Dr. F. H. HATCH, Pres. Inst. Min. & Met., etc.

of Ore-deposition.

(*d*) **Vadose Waters.**	(*e*) **Mechanical Agents** such as moving water and wind.	(*f*) **Chemical and Bacterial Agents** in seas, lakes, and swamps.
1.		
2. Superficial fracture-fillings, such as gash-veins in limestones and cavity-fillings (e.g. the hæmatite ores of Cumberland).		
3. Some lead and zinc ores in limestones. Iron-ores replacing limestones (e.g. Cleveland). Some lateritic iron and manganese deposits. Secondary enrichments of copper ores.		
4. Some lead and copper ores interstitial in sandstones and shales.	Mechanical concentrates in bedded deposits (e.g. gold and platinum placers, stream-tin, iron-sands, detrital laterites, and other metalliferous gravels and sands).	Chemical and bacterial sediments (e.g. lake- and bog-iron ores, clay-ironstone and other sedimentary siderites, bog-manganese-ore and other sedimentary manganese ores).
5. Mantle-deposits, e.g. pisolitic and nodular ores of iron (e.g. the Bilbao and Appalachian hæmatites and limonites), of manganese (psilomelane), and of aluminium (bauxite).	Eluvial gravels formed near the outcrop of veins (e.g. those of gold, cassiterite, wolfram, galena and zinc ores).	

REVIEWS.

I.—The Palæontographical Society, 1847–1914.

Issue of Vol. LXVII, for 1913. Agents for the Society, Dulau & Co., Ltd., 37 Soho Square, London, W.

Contents.

1. British Graptolites. By Miss Elles & Miss Wood (Mrs. Shakespear). Edited by Professor Lapworth. Part X. pp. 487–526, pls. l–lii.
2. A Monograph of the British Palæozoic Asterozoa. By W. K. Spencer, B.A., F.G.S. Part I. pp. 1–56, pl. i.
3. The Lower Palæozoic Trilobites of Girvan (supplement). By F. R. Cowper Reed, M.A., Sc.D., F.G.S. pp. 1–56, pls. i–viii.
4. The Pliocene Mollusca of Great Britain (supplementary to S. V. Wood's Monograph of the Crag Mollusca). By F. W. Harmer, F.G.S., F.R.Met.S. Part I. pp. 1–200, pls. i–xxiv.
5. The Ganoid Fishes of the British Carboniferous Formations. By Ramsay H. Traquair, M.D., LL.D., F.R.S. Part I, No. 7: Palæoniscidæ. pp. 181–6, with title-page and indexes.
6. Title-page and Systematic Index to complete a Monograph of the Fishes of the Old Red Sandstone of Britain. By R. H. Traquair, M.D., LL.D., F.R.S.

THE Council of the Palæontographical Society, its officers and subscribers, have reason for congratulation on the issue of their sixty-seventh annual volume (for 1913), under date of February, 1914. Age has not in any way diminished the lustre or lessened the artistic beauty or scientific value of the work published from year to year by this most important Society, and, despite the losses sustained both amongst its distinguished authors and its valued subscribers, new authors arise to add fresh contributions to its pages and new subscribers to replenish its funds, although the latter need to be greatly increased if similar splendid volumes, such as that now lying before us, are to be produced in this and future years.

1. The sixty-seventh volume opens with the tenth part of the monograph on British Graptolites, by Miss Elles & Miss Wood (Mrs. Shakespear), edited by Professor Lapworth. This valuable work was commenced in the fifty-fifth volume, for 1901, and has been continued (with only three intervals of a year each) up to the present time. It will probably be completed in another part. The Graptolites form a remarkable group which students of the existing Hydromedusæ generally dismiss in a very summary fashion as "a class known only in a fossil state, divided into three orders, which possibly bear but little genetic affinity to one another": 1, the Dendroidea; 2, the Graptoloidea—(*a*) Monoprionidæ, (*b*) Diprionidæ; 3, Retioloidea. But as among existing forms referred to this class their life-history has yet largely to be worked out, we may rejoice to find that by the combined labours of a large number of able investigators the Graptoloidea have now been well and carefully defined and have become, as *zonal indices*, of the highest importance in the Lower Palæozoic rocks.

The first detailed arrangement in successive chronological zones was made by Lapworth in his memoir "On the Geological Distribution of the Rhabdophora" (Ann. Mag. Nat. Hist. (5), vols. iii–vi, 1879–80).

A comparison of this memoir with the present monograph, as summarized in Table A, pp. 516–25, and Table B, p. 526, of this part, affords a striking index of the advance in our knowledge of the Graptoloidea during the thirty-three years interval which separates these works. In the earlier memoir the species and varieties numbered 284, distributed over some 20 Graptolite zones; the zones are now increased to 36, and the species have risen to 372.

All praise is due to the two lady authors, who, under the editorial criticism of Professor Lapworth, have so ably carried on the task of preparing this excellent monograph, now nearly completed.

2. Under the title of "British Palæozoic Asterozoa", Mr. W. K. Spencer, a new author, commences part i of a new work, and by way of introduction gives us a charmingly illustrated description of the minute anatomy of the hard parts of these interesting ancient star-fishes and their modern allies, one plate and thirty-one text-figures being used to render his explanations and nomenclature of parts clear to the reader. A bibliography of eighty-three works, relating to the literature of the subject, is also given.

3. Mr. F. R. Cowper Reed adds a supplement to his monograph of 1906 on "The Lower Palæozoic Trilobites of Girvan, Ayrshire", in order to describe twenty-three new species and three new varieties, obtained by Mrs. Gray, of Edinburgh, and to make sundry emendations and additions to his work. Eight excellent plates are also given of these new forms.

4. Mr. F. W. Harmer, a second new author, contributes part i of a monograph on Pliocene Mollusca (being by way of a supplementary monograph to S. V. Wood's Crag Mollusca commenced in 1847). Mr. Harmer, together with other workers, have added between six and seven hundred species to the Crag fauna of Walton (but chiefly from Little Oakley), from which, in Wood's time, less than 150 species were known. Mr. Harmer's contribution to this volume occupies 200 pages, and the illustrations fill twenty-four collotype plates, which being photographed from the actual specimens gives them a trustworthiness and reliability which the student of species will greatly appreciate. After an introductory section on the localities and the recent literature we come to the description of the Terrestrial Mollusca (twenty-four) and a number of freshwater forms (twenty-four), also from the Crag deposits. Following upon these we have the Marine Mollusca of the Crag, commencing with the Gasteropoda (pp. 49–200). But we must revert to Mr. Harmer's admirable monograph later, as our space is limited.

5 and 6. These consist of the closing pages on the Ganoid Fishes of the British Carboniferous Formations (with the title-pages and indexes) and the fishes of the Old Red Sandstone—closing the labours of our old friend and fellow-contributor, Dr. R. H. Traquair, F.R.S.

The indices to these volumes have been most carefully and kindly contributed by our able Secretary, Dr. Arthur Smith Woodward, F.R.S., whose valuable services in the production of this large and handsome volume all palæontologists will most gladly and gratefully acknowledge.

II.—Catalogue of the Mesozoic Plants in the British Museum. Part V: The Cretaceous Flora. Part 1: Bibliography, Algæ, and Fungi. By M. C. Stopes, D.Sc., etc. pp. xxiv, 286, with 2 plates and 25 text-figures. London: Dulau & Co., 1913. 12*s*.

IT is now ten years since the last part of the Catalogue of Mesozoic Plants was issued. The first four parts, by Professor Seward, dealt with the Jurassic and Wealden Floras, and the work is now being continued into the Cretaceous by Dr. Stopes. The present volume consists mainly of an exhaustive bibliography of the flora of the period, which unfortunately could only be brought up to the end of 1910. The list of species, which is not intended to be critical, contains references as far as possible to every Cretaceous plant, with the name and horizon originally given. The Wealden of Europe is omitted, since it was dealt with by Professor Seward, but the lower Cretaceous of North America, with its rich flora, is included. Though many cross-references are given in cases where species have been removed from one genus to another, no attempt has been made to make the list complete in this respect, as Dr. Stopes only includes "any renaming that was enlightening, or accompanied by any original work on the specimen". Nevertheless, the list will form a useful work of reference for future workers in this department of fossil botany.

The descriptive part of the catalogue deals only with the Algæ and Fungi, and owing to the scarcity of well-authenticated fossil examples of these groups, there is not much to be said about them. In the case of the algæ the calcareous forms are the most interesting, since their structure can often be studied under the microscope, while recently their importance as rock-builders has been much discussed. Several genera of the Siphoneæ are represented in the Cretaceous, besides the red alga *Lithothamnion*. The remaining "algæ", apart from diatoms, are impressions only, and though some are probably of an algal nature the great majority are extremely doubtful. Dr. Stopes gives a list of seventy-eight "species" which may be dismissed as mere tracks or indeterminable specimens.

The Fungi are even more poorly represented. Only four of those enumerated occur in a petrified state, and one of these, *Trametites pini* (Conw.), is merely a mycelium, while *Petrosphæria japonica*, Stopes & Fujii, is little better, and shows no reproductive organs by which its family might be determined. In *Trichosporites Conwentzi*, Felix, spores are associated with the hyphæ, but the illustration shows no evidence of attachment. The only well-preserved species is that called *Pleosporites Shirainus*, Suzuki, but even here the apparent asci contain no ascospores, so that the generic affinities are doubtful. Dr. Stopes suggests that different "biological species" of this fungus may have been adapted to the different species of *Cryptomeriopsis* in which it occurs, but are such "biological species" found among Ascomycetes at all? The other "phenomena described as fungi" are markings on leaves, often of a very doubtful nature. Dr. Stopes uses Gothic type for the names of "fossil plants for which there is no

good, scientific reason for association with given families and genera, and to which, nevertheless, names indicative of such affinities have been given", and most of the fungi might well have been black-listed in this way.

The Introduction contains a short account of Cretaceous plant-bearing deposits in various parts of the world, with a useful table giving approximate correlations of the different beds.

III.—Paléontologie Végétale : Cryptogames Cellulaires et Cryptogames Vasculaires. By F. Pelourde. pp. 360, with 80 text-figures. Paris : O. Doin et fils, 1914. 5 fr. London : Dulau & Co.

THIS is the first volume to appear in the palæontogical section of a new Encyclopédie Scientifique. The aim of the series, which is to comprise about a thousand volumes, is to provide a critical summary of the present state of scientific knowledge in all its branches. There are to be two more volumes on palæobotany, one dealing with gymnosperms and the other with angiosperms and general conclusions, and these will in some respects be more interesting than the first, for they will deal with less familiar ground. We already have several excellent textbooks of fossil botany, and it might be thought that there was little room for the present compilation. It will, however, prove extremely useful to students, for it is of a handy size, and will easily slip into the pocket, and the facts are on the whole well chosen and concisely arranged. A marvellous amount of information has been compressed into a small space, and the account of the stem structure of *Sigillaria*, for example, is particularly clear, as also is the section dealing with the ferns. It is a pity that many of the illustrations, especially the reproductions of photographs, are so poor.

In matters of detail a few criticisms may be made. Thus in the geological table the Silurian system is divided into Cambrian, Ordovician, and Gothlandian, each being apparently equivalent to each of the six subdivisions of the Devonian, which would be rather misleading to the non-geological reader. *Lepidodendron saalfeldense* and other petrified plants from Saalfeld, Thuringia, are undoubtedly of Lower Carboniferous and not Devonian age (p. 118) and the genus *Megalopteris* was erroneously described by Dawson as Devonian (p. 224). In view of our ignorance as to the limits of the Pteridospermæ, where fronds alone are concerned, it is a rather sweeping assertion that the immense majority of Pecopterids belonged to the Marattiales, while many of the supposed Marattiaceous sporangia may well be microsporangia of Pteridosperms. There is very little known of fossil thallophytes and bryophytes, and in Dr. Pelourde's necessarily short account such a doubtful specimen as Matthew's supposed Palæozoic lichen might well have been omitted.

The bibliography calls for some comment. The paging is usually and dates occasionally omitted, and such a reference as "Lesquereux. Geol. of Penn'a, II" is quite inadequate. Several references given in the text do not appear in the bibliography. One of Williamson's

papers is credited to Mr. Kidston ("Kidston, 3"). The practice of omitting authors' initials leads to the confusion, for example, of the late German palæobotanist, C. E. Weiss, with the present professor of botany at Manchester; while similarly (see index) no distinction is made between Professor W. P. Thomas and Mr. Hamshaw Thomas of Cambridge.

In other respects, however, Dr. Pelourde has produced an excellent condensed account of fossil plants, as far as the Pteridophytes, in the light of modern knowledge.

IV.—Australasian Fossils: A Student's Manual of Palæontology. By Frederick Chapman, Palæontologist to the National Museum, Melbourne. pp. 341, 150 figures, and map. Melbourne, Sydney, Adelaide, Brisbane, and London: George Robertson & Co., 1914.

MR. CHAPMAN has in numerous memoirs added largely to our knowledge of the fossil flora and fauna of the Southern Hemisphere, and, in the work now before us, has conferred a great boon upon all students of geology in the Dominions of Australia and New Zealand. The necessity of such a work as the present will be manifest to everyone who remembers that in all the published geological treatises the examples and illustrations given are those of the fossils of Europe and North America; the descriptions and figures supplied by Mr. Chapman will serve to admirably redress this grievance of geological students at the Antipodes.

In a short, but very clear, introduction to the book Professor Skeats admirably summarizes the principles of palæontological science. In the body of the work the author, after some preliminary chapters, gives an account of the fossils of each of the great classes of plants and animals, the arrangement in each class being a stratigraphical one, while the very numerous figures admirably illustrate the text. At the end of each chapter there is given a list of the common or characteristic forms of the group described, with complete series of references to the literature dealing with the class of organisms.

The work closes with an appendix on the collection and preservation of fossils, to which is added a list of fossil localities, illustrated by a map of Australia and New Zealand, on which the position of these localities is shown. The work cannot fail to be of great service, not only to students, but to all interested in geological studies on the other side of the globe.

V.—Tennessee State Geological Survey.

Bulletin 16. The Red Iron Ores of East Tennessee. By Ernest F. Burchard. pp. 173, with 17 plates (including 5 maps) and 30 figures in the text. 1913.

THIS bulletin describes the ore-deposits situated in the northern part of the Chatanooga District of East Tennessee, and discusses very briefly the ore-bearing formations and the rocks immediately associated with them. Deposits of ore occur in three formations: the Tellico Sandstone (Ordovician), the Rockwood formation (Silurian),

and the Grainger Shale (Carboniferous). The deposits in the Grainger Shale are of very little importance. The ores of the Tellico Sandstone are 'replacement ores', and are due to the leaching out by surface agencies of the calcium carbonate from beds of ferruginous limestone. The deposits of the Rockwood formation belong, however, to the 'Clinton type' of iron-ore; they occur as lenticular beds of hematite analogous to the strata of sandstone, shale, and limestone with which they are associated, and consist of a mixture of 'fossil ore' and 'granular ore'.

Fossil ore consists of aggregates of fragments of crinoids, corals, brachiopods, and trilobites, many of which still consist of calcite, but in places they are now wholly composed of ferric oxide. Granular ore is a variety of oolitic ore, consisting of flattened grains lying with their flat sides parallel to the bedding and cemented by ferric oxide; the grains often contain a nucleus of quartz.

These hematite beds were formed by the deposition in the waters of shallow bays or lagoons of sediments containing iron together with calcium carbonate, silica, and alumina. Much of the calcium carbonate was deposited as fragments of fossils. There is no evidence that the iron was introduced from other beds of the Rockwood or any other formation. It is held that the replacement of calcium carbonate by ferric oxide may have taken place quite early in the history of the deposits, and that the unweathered ores were formed in essentially their present condition, contemporaneously with the associated sandstone and shale.

The distinction between the mode of formation of 'replacement ores' and of ores of the Clinton type is one of great economic importance, for those of the Clinton type will not be expected to show any regular decrease of iron content in depth, which is usually the case with 'replacement ores'.

The bulletin contains detailed descriptions and sections of the mining prospects, and concludes with some useful notes on mining and on the iron industry.

VI.—Water and Volcanic Activity. By A. L. Day & E. S. Shepherd. Bull. Geol. Soc. America, vol. xxiv, pp. 573–606, pls. xvii–xxvii.

In a previous issue of this journal there appeared a review of a very striking work entitled *Recherches sur l'exhalaison volcanique*, by Albert Brun, a chemist of Geneva. Brun was impressed by the frequent absence of evidence for the widely accepted aqueous theory of volcanoes; he had accordingly devoted his spare time to the study of various active craters, and had been led to the conclusion that in paroxysmal eruptions water does not exist among the gases emanated. Much of the evidence for this conclusion was derived from the study of Kilauea, where Lowthian Green had been led to the same conclusion as Brun as early as 1887. The American geologists have taken up the challenge and have sought to make a careful examination of the emanations from Kilauea in order to test the validity of Brun's conclusions.

The gases examined by Brun were collected by means of tubes, the end of which was 250 feet above the surface of the lava; these

gases were consequently already *burnt* and mixed with air. To obtain unburnt gases the authors made descents into the crater, at considerable danger to themselves, and pumped the gases through a set of tubes the end of which, cased in iron, extended for a foot into a vent in a dome of lava on the crater-floor. In fifteen minutes, during which 1,000 litres of gas may have passed through the glass tubes, the authors obtained about 300 c.c. of water. A second attempt was made to collect the gases in vacuum tubes and so find the relative proportions of the constituents, but the experiment was vitiated by access of air from another vent; however, the figures obtained indicate that water was present to the extent of 26 per cent by weight. It is therefore clear that water does play an important rôle in the emanations from Kilauea, and that Brun's conclusions in this respect are false. Many of Brun's arguments are based on observations of the cloud over the lava in the crater pit of Kilauea and on hygrometric measurements, but it is shown that his deductions from these observations were incorrect.

Further interesting deductions may be made from the study of the emanations of Kilauea. The gases detected include nitrogen, hydrogen, water, carbon dioxide, carbon monoxide, hydrogen, and sulphur, with traces of chlorine, fluorine, and, possibly, ammonia. These gases issue from vents in the lava at a temperature near 1,000° C., a temperature at which they cannot possibly be in equilibrium under atmospheric pressure. Diminution in pressure may cause interactions which probably produce a heating effect far exceeding the cooling effect due to expansion; thus the gases may be hotter at the surface than in depth. In support of this idea it is noted that the temperature of the lava rises with the quantity of gas given off. With regard to the origin of the water, the authors find themselves unable to conceive of any mechanism whereby atmospheric or surface waters could reach the magma basins. Further, the very important fact that *argon* is absent in the emanations of Kilauea proves that atmospheric gases have not reached the magma basins. The water of the emanations "must be considered as an original constituent with as much right as the sulphur or the carbon".

VII.—Directions for the Collection of Geological Specimens. By Dr. J. W. Evans, LL.B., F.G.S. Colonial Office, Miscell. No. 283.

UNDER this title the Colonial Office have issued a tract by Dr. J. W. Evans, giving explicit instructions as to what to do and what to avoid. It cannot be too often said that many of those who travel to little-visited parts of the world are entirely ignorant of the simplest geological knowledge, and with every intention of bringing home specimens often collect useless material. In this tract the traveller is told exactly what is likely to be of use, how to obtain it, how to label and pack it, and how to make his notes on what is collected. The few pages (twenty) will hardly form impedimenta in his baggage, and the knowledge he will obtain from a perusal of the tract will, even if he does not happen to do any collecting, greatly increase the

interest of his wanderings. The tract is referred to as Colonial Office, Miscell. No. 283, and as no price is attached can be had for the asking.

VIII.—Canada: Department of Mines.

1. Austin Brook Iron-bearing District, New Brunswick. By E. Lindeman. pp. 15, with 3 plates, 5 figures, and 3 maps. 1913.

THIS report is based on a magnetometric survey of the areas, of which a preliminary report was issued in 1906. The ore consists of very fine-grained siliceous magnetite mixed with a considerable amount of hematite. It occurs as dyke-like masses in a quartz-porphyry, which is itself intruded into slates, possibly Devonian in age. Analyses are given of eight samples of ore, and there are details of the cores obtained from four borings. The maps accompanying the report include magnetometric and geological maps on a scale of 400 feet to the inch, and a smaller scale map showing the location of the district.

2. Magnetite Occurrences along the Central Ontario Railway. By E. Lindeman. pp. 23, with 9 plates and 19 maps. 1913.

The deposits of magnetite here considered occur between Central Ontario Junction and the village of Bancroft, a distance of about 60 miles. The greater part of this area is occupied by Archæan rocks, consisting of crystalline limestones, para-gneisses, schists, and amphibolites, intruded by granite, syenite, diorite, and gabbro, and in places overlain by the lowest beds of the Palæozoic Series.

The magnetite occurs as irregular masses interbanded with crystalline limestones and schists usually along or near their contacts with intrusive diorite; they are regarded as a result of the contact action of the igneous rocks on the limestone, as they contain many minerals characteristic of this type of metamorphism. In addition to this there are small occurrences of titaniferous magnetite representing local concentrations in a gabbro.

The area being largely drift-covered, the careful use of a systematic magnetometric survey has been of the greatest value. The report is accompanied by eighteen maps, magnetometric and geological, on a scale of 200 feet to the inch, and by an index map showing the location of the deposits. The various deposits and mines are described in detail, but there seems little hope of any of the deposits being of great economic importance.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *February* 25, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "Acid and Intermediate Intrusions and Associated Ash-Necks in the Neighbourhood of Melrose (Roxburghshire)." By

Rachael Workman McRobert, B.Sc. (Communicated by E. B. Bailey, B.A., F.G.S.)

This communication deals with the igneous rocks which fall within an area about 7 miles square, included in Sheet 25 of the Geological Survey map of Scotland, and which lie in the neighbourhood of Galashiels, Selkirk, and Melrose. The age usually assigned to the igneous intrusions is a late period in the history of the 'plateau-eruptions' of Calciferous Sandstone times, and thus corresponds to those of the trachytic lavas and intrusions of the Campsie and Renfrewshire Hills.

The relation of the igneous rocks to the Old Red Sandstone is discussed, and new localities are cited where a protective covering of igneous rocks has resulted in the preservation of small outliers of Old Red Sandstone, far removed from the main outcrop of the formation.

The main portion of the paper deals with the petrology of the igneous rocks, which occur as laccolites and sills, as dykes having for the most part a north-easterly direction, and in volcanic necks.

The chief rock-types present in the area described may be summarized as follows: Porphyritic and non-porphyritic sanidine-trachytes, quartz-trachytes, riebeckite-felsites, quartz-porphyries, basalts, and volcanic agglomerates. The sanidine-trachytes present a number of varieties, characterized either by the presence of fresh riebeckite, by the presence of ægirine-augite and olivine, or by the absence of any fresh ferromagnesian minerals. The more acid types described may be regarded as standing midway between the phonolites and trachytes of the same age which occur south-east of Hawick and those of East Lothian.

In addition to the description of the various rock-types which occur as isolated sills and dykes, the geology of the Eildon Hills is discussed in some detail, and a petrographical account is given of the rocks in that region. The author has traced as far as possible the distribution of the various rock-types, and has come to the conclusion that the Eildon Hills form the eastern section of a composite, complex laccolite. A basaltic neck has been met with in the Eildon Hill complex, and appears to cut through the more acid intrusions which form the main portion of the Eildon Hills. The record of riebeckite in the rocks of this region has been considerably extended.

The salient features of the suite of rocks described are the high content of alkalies and the presence of soda-bearing minerals such as riebeckite, ægirine-augite, primary albite, and soda-orthoclase. Nepheline, however, though its presence might be expected in some instances, was found to be absent from most of the rocks.

2. "Correlation of Dinantian and Avonian." By Arthur Vaughan, M.A., D.Sc., F.G.S.

The present paper records the results of applying the time-scale deduced from the South-Western Province to the Belgian sequence, and shows that the faunal succession is practically the same in both provinces. Even the specialized and locally exaggerated facies which form so striking a feature of the Belgian Province (such as the 'petit

granit', the 'Waulsortian', and the '*sublævis* oolite') have been discovered at certain points of the South-Western Province, and they are adumbrated at many others. [If, furthermore, we extend our researches and compare the Midland and Northern developments of England and Wales with that of Belgium, striking identities are observed; for example—

The 'Brachiopod Beds' of the Midlands and of Visé are identical.
The lower 'knolls' of the Clitheroe area are typical 'Waulsortian'.]

The following are the most important conclusions from the author's work in Belgium:—

(1) *Physiographical Phenomena.*—The lateral variation of Mid-Avonian lithology is strikingly exhibited in a diagram. Minute correlation of the Belgian sequence with that of the South-Western Province demonstrates that the periods of partial emergence, of the west of the South-Western Province and of the east of the Belgian Province, took place consecutively and not simultaneously, namely: in the South-Western Province at the close of C_1 time, in Belgium at the beginning of Viséan time. At the latter period England and Wales, outside the South-Western Province, had sunk below the Carboniferous sea. [Simultaneously, however, Ireland was, like Belgium, under emergent conditions.]

(2) *Palæontological Phenomena.*—The palæontological section contains descriptions of several gentes that are common in Belgium, but rare in Britain. The most interesting portion of the section is, however, that which deals with the evolution of the important Carboniferous corals and brachiopods. Two illustrations were selected, and were shown as lantern-slides:—

1. Phylogenetic history of *Caninia cylindrica*.
   Belgium only { K. *Endophyllum*.
   { Z. *Caninia hastierensis* (Endophylloid).
   Migration into Britain at γ—*C. cylindrica*, mut. γ.
   Britain and Belgium . δ and S—mature (Campophylloid) *Caninia*.
2. Fragments of the history of *Spiriferina octoplicata*, showing variation of relative strength of ribs (departure from normality of early stages)—the essential characters fixed.

These facts concerning migration and evolution are, unquestionably, the most important results of extending the area of observation.

The author has received continuous and invaluable assistance from Professor G. Delépine and from Mr. E. E. L. Dixon; he is also very deeply indebted to the recent works of Professor Delépine and Dr. A. Carpentier (Northern France), from which he has cited freely.

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2. *March* 11, 1914.—Dr. A. Smith Woodward, F.R.S., President, and afterwards Dr. H. H. Bemrose, J.P., Vice-President, in the Chair.

Mr. E. T. Newton, in exhibiting a series of small mammalian and other remains from the rock-shelter of La Columbière, near Poncin (Ain), said that, during the year 1913, Dr. Lucien Mayet and M. Jean Pissot were working systematically at the prolific deposits of this locality, and towards the end of the year made known the

discovery of a number of incised bones and stones, representing the human form as well as several animals. This discovery was published in the C. R. Acad. Sci. Paris (vol. clvii, p. 665), and some account of it, with several figures, appeared in the *Illustrated London News* for November 1, 1913.

The upper part of the deposit is referred to the Neolithic and Magdalenian ages; but below this, at a depth of 6½ feet, a bed (10 inches thick) was found, which yielded the incised drawings above mentioned, as well as numerous mammalian remains and flint implements; and this is regarded as of Aurignacian age. Immediately below the last-mentioned bed a deposit of sand and small rock-fragments was penetrated to a depth of 10 feet, and this deposit, also referred to the Aurignacian, was found to contain an enormous number of bones of small mammals and other animals. Some twenty species have already been recognized by the discoverers.

The large number of small bones now shown were obtained by the exhibitor in sifting about 1 cubic foot of this lower, remarkably prolific, deposit, which had been sent to him by Dr. Lucien Mayet, of Lyons.

The following communication was read:—

"On an apparently Palæolithic Engraving on a Bone from Sherborne (Dorset)." By Arthur Smith Woodward, LL.D., F.R.S., Pres.G.S.

The author is indebted to Mr. R. Elliot Steel, of Sherborne School, for the opportunity of studying a fragment of bone bearing an incised drawing of the fore-part of a horse in the style of drawings already well known from several habitations of Palæolithic man. The specimen was found by schoolboys in an old mound of débris from a quarry in the Inferior Oolite near Sherborne. Nothing is known of the circumstances under which it originally occurred; but the situation of the quarry is in a small dry valley, on a steep slope facing south-westwards, and the bone may perhaps have been removed with the remains of a rock-shelter. No associated specimens of any interest were recovered; but at the lower end of the same valley, about a quarter of a mile distant, teeth of mammoth and woolly rhinoceros have been found. Like the only other British specimen hitherto discovered—that described by Professor Boyd Dawkins from the Creswell caves—the drawing is made on a fragment of rib; and the neck of the horse is fringed by fine lines, which indicate the short hog-mane usual in sketches made by the Palæolithic race.

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3. *March* 25, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for the present year to Percy George Hamnall Boswell, B.Sc., F.G.S., who proposes to investigate the stratigraphy and petrology of the Lower Eocene strata of the north-eastern portion of the London Basin.

Professor J. W. Judd, C.B., F.R.S., gave the following general account of the geology of Rockall[1]:—

Rockall is a small isolated rock in mid-Atlantic, lying 184 miles west of St. Kilda; it has a circumference of only 100 yards and a height of 70 feet, and, except in the very calmest weather, is quite inaccessible. It is the haunt of sea-birds and, with its whitened top, resembles a sailing ship, for which it has often been mistaken. The rock rises from a bank (the 'Rockall Bank') upon which there are several dangerous reefs.

More than 300 years ago it was reported that a large island occupied the site of Rockall, and, for a hundred years or more, all Atlantic charts represented this island, which was named 'Busse Island', with a number of other islands and islets, as present in the North Atlantic. Taking these supposed facts in connexion with the famous classical stories of an 'Atlantis', the theory was often advanced that the North Atlantic was an area of subsidence, and that the reported islands—and, in the end, Rockall—were the last vestiges of the famous vanished continent. Modern research has, however, quite disposed of this theory.

Nevertheless, Rockall is of considerable interest, especially to geologists. In 1810 Basil Hall, then a young officer in H.M.S. *Endymion*, obtained a fragment from this rock, which later found its way into the collection of the Geological Society. More than thirty years afterwards the specimen was recognized; it was then mislaid for another thirty years, and in 1895 was brought to me by the late Professor T. Rupert Jones.

He not only carefully studied all the literature connected with Rockall, but was able to trace two other specimens of the rock, the loan of which he obtained and brought to me. They had been procured by two of the officers of H.M.S. *Porcupine* in 1868 during the survey of the North Atlantic. The microscopic study of these specimens shows that in Rockall there exist rocks of exceptional interest, which are not represented in our Islands, but have analogies in the Christiania district of Norway, where they have been so well studied by Professor W. C. Brögger. These rocks, as shown by microscopic study and by a chemical analysis made by Mr. Makins, consist essentially of three minerals—quartz, the felspar albite, and the rare soda-pyroxene ægirite, with its dimorphous form acmite. The rock, therefore, resembles the soda-granite and the grorudite of Professor Brögger, but, in deference to the opinion of the distinguished Norwegian petrographer, a distinct name was given to it.

In 1896 an attempt was made to obtain further specimens of the rocks of this islet by members of the Royal Irish Academy; but, although many valuable observations were recorded, it was found, after two voyages had been made to Rockall, quite impossible to land and obtain specimens.

Dredging operations have yielded many specimens from the Rockall Bank, and these were examined by the late David Forbes and Professor Grenville A. J. Cole. The abundance of basalt fragments among these dredgings suggests the possibility of Rockall belonging to the same petrographical province as St. Kilda, Iceland, the Inner Hebrides, and the North of Ireland; hitherto, I believe, no rocks resembling 'rockallite' have been found in this province. On the other hand, the existence of borolanite and other alkaline rocks in the Northern Highlands suggests the possibility of Rockall being the western extension of a much older province, which includes the Christiania district and the Scottish Highlands.

Some months ago Professor Iddings and Dr. Washington represented to me the desirability of a more detailed analysis of this rock. One of the two small fragments available was, by the advice of Professor Watts, sent to America by the Council of the Imperial College of Science and Technology, to whom they

[1] For an account of "Rockall Island and Bank" see GEOL. MAG., 1899, pp. 163–7, and Trans. Roy. Irish Acad., vol. xxxi, pt. iii, pp. 39–98, pls. ix–xiv, 1897.

belonged, and the paper now about to be read gives the result of the study of this minute specimen by Dr. Washington.

The following communication was read:—

"The Composition of Rockallite." By Dr. Henry S. Washington, For. Corr. G.S.

The paper centres around a detailed chemical analysis made by the author of the type-material of rockallite, an igneous rock of exceptional chemical and mineralogical composition.

A petrographical account is given of the rock, with special reference to the influence of the constituent minerals upon the bulk-analysis.

Rockallite has a fine-grained granitic structure, and is composed of about equal amounts of colourless quartz, alkaline felspar, and soda-pyroxene. The pyroxene is of two kinds, a bright grass-green ægirite and a pale yellowish-brown acmite. Some zircon is present, but not to more than a tenth of 1 per cent of the rock.

A chemical analysis has been made with the greatest care, according to the methods advocated by Hillebrand and the author, zirconia and the rare earths being especially looked for. The main results of the analysis confirm those of Makins, but several new points of interest have presented themselves. The outstanding features of the rock appear to be the high percentages of silica, ferric oxide, and soda, and the low percentages of alumina, ferrous oxide, magnesia, lime, and potash. The special interest of the new analysis, however, lies in the detection of zirconia and cerium oxide in unexpectedly large amounts, the percentage of cerium oxide being larger than that from any known igneous rock, with the exception of the nepheline-syenite from Almunge in Sweden.

The author has calculated the norm from the old and the new analyses, and finds that the rock falls into the subrang rockallose with the general symbol III. 3. I. 5. He notes, as indicating the exceptional character of the rock, that these analyses are the only representatives of the subrang rockallose among the 8,000 analyses of igneous rocks that he has now collected.

The author concludes with a discussion of the affinities of rockallite, and a consideration of the probable chemical composition of the ægirite and acmite. He clearly proves that the zirconia and cerium oxide enter into the composition of the pyroxenes.

II.—Mineralogical Society of London.

March 17, 1914.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

F. P. Mennell: On an occurrence of Bornite Nodules in shale from Mashonaland. The ore-body of the Umkondo mine in South-East Mashonaland consists of a bed of shale through which are scattered nodules of bornite, most probably pseudomorphous after concretionary pyrites. The enclosing rocks are of the same age as the Waterberg Series of the Transvaal, and contain pseudomorphs after salt in some of the shale bands. The occurrence of copper and salt at nearly the same horizon is paralleled in the Lower Keuper beds of Europe.—A. Scott: Augite from Bail Hill, Dumfriesshire. It occurs in crystals,

which are black in colour, but yellowish-green in thin sections, and of two types, simple and twinned, and have the axial constants $a : b : c = 0{\cdot}5844 : 1 : 1{\cdot}0932$, $\beta = 105° 48'$, and refractive indices 1·708, 1·713, 1·728. Sections parallel to the plane of symmetry show the hour-glass structure characteristic of titaniferous augite.—Dr. G. T. Prior: On a Sulpharsenite of Lead from the Binnenthal. Analysis of the crystals, on which the prism zone alone was developed, showed that the composition corresponded to the formula $3\,PbS\,.\,2\,As_2S_3$, which is that attributed to rathite; crystallographically, however, the crystals seem nearer to dufrenoysite.—Dr. G. T. Prior: On Phacolite and Gmelinite from County Antrim. In both instances analysis of these minerals, which are varieties of the same species, differing in habit of crystal, showed an excess of hydrated silica over the composition represented by the formula $(Ca, Na_2)\,Al_2\,Si_4\,O_{12}\,.\,6\,H_2O$.

III.—Edinburgh Geological Society.

March 25, 1914.—Dr. John S. Flett, F.R.S., President, in the Chair.

1. "On a Visit to the Klondyke Goldfields." 2. "The Glaciation of Alaska." (Illustrated.) By H. M. Cadell, B.Sc., F.R.S.E.

The object of the papers was to give an account of the Klondyke goldfields and the glaciers of Alaska visited by the author last autumn.

During last century there had been a great shrinkage in the glaciers, but some of them had begun to advance since the great earthquake in September, 1899. The traces of the earthquake were still very distinct. Parts of the coast were upraised 40 feet in places, and gaping fault-fissures were plainly seen. On the way from the watershed towards Dawson City and Klondyke the signs of glaciation became less and less, and in the goldfields it was clear there had never been any glacial action at all, though it lay so far north.

The old plain gravels in the Klondyke valley and other places had never been disturbed since Pliocene times, except by changes in the river system that had occurred in consequence of alterations of the level of the land. This absence of ice was due to the dryness of climate in the Glacial period in that region, and not to a warmer climate. The gold-bearing gravels were frozen solid to a depth of 100 feet, and contained bones and tusks of mammoths and other animals. There were two sets of placer gravels, one in the bottom, and another higher up on the side of a few of the valleys. The older gravels had no animal remains in them, and were nearly white in colour. The level had been upheaved 700 feet, and the rivers had cut out deeper glens before the newer gravels were produced, and the gold was washed out and deposited in the beds of the creeks, where it had lately been, and still was being worked, but on a smaller scale than in 1900.

The total yield of the goldfield was about £30,000,000, and in 1913 there was still a production of £1,000,000 by dredging and hydraulic sluicing companies with a large capital. Klondyke was no longer a poor man's goldfield, and there was still a good deal of gravel that could be profitably worked by means of extensive plant.